MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS, ABSTRACTS OF PAPERS, AND
REPORTS OF THE PROCEEDINGS
OF THE SOCIETY

FROM NOVEMBER 1898 *TO NOVEMBER* 1899.

VOL. LIX.

LONDON:
ROYAL ASTRONOMICAL SOCIETY,
BURLINGTON HOUSE, W.
1899

PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
LONDON

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ROYAL ASTRONOMICAL SOCIETY.

Vol. LIX. November 11, 1898. No. 1

Sir R. S. Ball, LL.D., F.R.S., President, in the Chair.

Andrew Ellicott Douglass, B.A., Lowell Observatory, Flagstaff, Arizona, U.S.A.; and

Cecil Goodrich Julius Dolmage, M.A., LL.D., 22 Upper Merrion Street, Dublin,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Arthur R. Hinks, 2nd Assistant, Cambridge Observatory (proposed by Sir R. S. Ball);

Charles Lewis Brook, Harewood Lodge, Meltham, Huddersfield (proposed by Rev. T. H. E. C. Espin);

Arthur Hands, L.R.C.P., M.R.C.S., Inkerman House, Wednesfield Road, Wolverhampton (proposed by Samuel Fellows);

Samuel Henry Harrison, F.R.G.S., Fellow of the Institute of Bankers, Frederick Road, Edgbaston, Birmingham (proposed by Sir J. Benjamin Stone); and

Worcester R. Warner, Engineer, Cleveland, Ohio, U.S.A. (proposed by W. H. Maw).

Two hundred and thirteen presents were announced as having been received since the last meeting, including, amongst others :—

Cape Photographic Durchmusterung, pt. 2, presented by the Observatory; Greenwich Observatory, Enlargements of photographs of Sun-spots, presented by the Astronomer Royal; Indian Survey Department, Observations of the eclipse of 1898, January 22, presented by the Department; F. McClean, Spectra of Southern Stars, presented by the author; G. J. Newbegin, Negatives of the Sun, 1898 September–October, presented by Mr. Newbegin; Paris Observatory, Atlas Photographique de la Lune, fasc. III., presented by the Observatory; R. Sewell, Eclipses of the Moon in India, presented by the author; L. Weinek, Photographischer Mond Atlas, Heft 3, presented by Professor Weinek; C. A. Young, The Sun, new edition, presented by the author; and, in addition to the above, a present from Mr. C. L. Prince of 43 works, including eight editions of Aratus, three of Manilius, &c.

Remarks on Dr. Gill's Paper in the Monthly Notices *for June.*
By Arthur A. Rambaut, M.A., D.Sc., Radcliffe Observer.

Having carefully read Dr. Gill's reply to my paper in the *Monthly Notices*, vol. lviii., No. 5, I cannot find anything in it that weakens in the least degree any of the arguments I have there adduced, and so far as the main contention is concerned I should be well content to allow it to be decided by what has already been written, and thus avoid cumbering the pages of the *Monthly Notices* with matter of a merely controversial kind.

I desire, however, to point out two mistakes—one on Dr. Gill's part, and one on my own.

1. The four types of equations which Dr. Gill has written (vol. lviii., p. 422) are not those which I have considered on p. 271 of the same volume, and therefore Dr. Gill's subsequent remarks have no bearing on my contention.

2. In the second group of equations on p. 263 I regret to say that an error has occurred which, so far as I am aware, has not been detected by Dr. Gill, or anyone else who has done me the honour of reading the paper.

I have there stated that the residuals denoted by the capital Vs are equal to the differences between the residuals denoted by small letters with corresponding suffixes and the constant error of the group, or that $V_{11}=v_{11}-a_1$; $V_{12}=v_{12}-a_1$; &c. This is not necessarily true, although it is very nearly so in the case before us. This error does not touch the main argument of the paper, its effect being confined to the second, third, and fourth paragraphs of p. 264, and the first four paragraphs of p. 265. Nor does it affect the sufficiently obvious result contained in the first paragraph of p. 264, viz., that the means of Dr. Gill's residuals in each group vanish identically. This is, however, of less consequence now that Dr. Gill disowns the argument founded on a comparison of his means and mine for each group of equations, which I referred to as being of no value whatever.

Dr. Gill says that he has never employed any such argument, and of course I accept his statement without reserve as implying that he had no intention of using it against me.

But I think it is most unfortunate that this comparison, in which the mean of my residuals appears, to the casual reader, to such a disadvantage as compared with Dr. Gill's, should have been inserted at that place (*Monthly Notices*, vol. lviii. p. 62), where Dr. Gill is showing in what respects my first solution is defective, or that my residuals should have been quoted at all, since the comparison was only given, as Dr. Gill tells us, to demonstrate the general arithmetical accuracy of his work, although this had never been called in question.

Radcliffe Observatory, Oxford:
1898 *October* 13.

Mean Areas and Heliographic Latitudes of Sun-spots in the year 1897, deduced from Photographs taken at the Royal Observatory, Greenwich; at Dehra Dûn (India); and in Mauritius.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. lviii., p. 307, and are deduced from the measurements of solar photographs taken at the Royal Observatory, Greenwich; at Dehra Dûn, India; and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily areas of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1897; and Table II. gives the same particulars for the entire year 1897 and the eight preceding years for the sake of comparison. The areas are given in two forms. First, projected areas—that is to say, as seen and measured on the photographs, these being expressed in millionths of the Sun's apparent disc; and next, areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. exhibits for each rotation in 1897 the mean daily area of whole spots, the mean heliographic latitude of the spotted area, and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole, similar results from 1889 to 1896 being added, as in the case of Table II. Tables II. and IV. are thus in continuation of the similar tables for the years 1874 to 1888 on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*.

The rotations in Table I. and Table III. are numbered in continuation of Carrington's series (*Observations of Solar Spots made at Redhill*, by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853, November 9. The assumed prime meridian is that which passed through the ascending node at mean noon on 1854, January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich civil time, reckoning from mean midnight.

Table I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected. Umbræ.	Projected. Whole Spots.	Projected. Faculæ.	Corrected for Foreshortening. Umbræ.	Corrected for Foreshortening. Whole Spots.	Corrected for Foreshortening. Faculæ.
	d							
579	1897 Jan. 8·08	28	338	1919	1651	230	1335	1888
580	Feb. 4·43	26	208	1086	1446	154	817	1694
581	Mar. 3·77	27	100	544	1085	82	455	1293
582	Mar. 31·07	28	101	528	1188	74	391	1358
583	Apr. 27·33	27	86	542	805	57	364	972
584	May 24·55	27	69	335	670	54	268	798
585	June 20·76	27	64	385	776	47	289	898
586	July 17·96	27	137	886	948	98	647	1092
587	Aug. 14·18	27	109	806	881	100	565	972
588	Sept. 10·43	28	99	551	1140	74	423	1358
589	Oct. 7·71	27	3	28	677	3	24	820
590	Nov. 4·00	27	8	42	536	6	33	658
591	Dec. 1·32	28	172	1019	884	128	798	1091

TABLE II.

Year.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected Umbræ.	Projected Whole Spots.	Projected Faculæ.	Corrected for Foreshortening. Umbræ.	Corrected Whole Spots.	Corrected Faculæ.
1889	360	17·9	103	107	13·1	78·0	131
1890	361	21·3	133	273	15·5	99·4	304
1891	363	120	745	1322	86·2	569	1412
1892	362	255	1596	3230	186	1214	3270
1893	362	327	1983	2287	234	1464	2404
1894	364	317	1728	1666	231	1282	1877
1895	364	237	1330	2059	169	974	2278
1896	364	127	745	1243	90	543	1410
1897	364	122	695	977	88	514	1149

TABLE III.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
				°		°	°	°
579	1897 Jan. 8·08	28	265	7·06	1070	7·67	− 4·74	7·55
580	Feb. 4·43	26	412	8·85	406	4·80	+ 2·07	6·84
581	Mar. 3·77	27	260	5·20	195	5·57	+ 0·59	5·36
582	Mar. 31·07	28	267	3·46	124	6·57	+ 0·28	4·44
583	Apr. 27·33	27	86	3·34	278	12·09	− 8·45	10·03
584	May 24·55	27	4	2·10	263	10·83	− 10·59	10·66
585	June 20·76	27	6	8·60	283	7·00	− 6·70	7·03
586	July 17·96	27	222	10·44	425	6·21	− 0·49	7·66
587	Aug. 14·18	27	57	14·36	508	7·83	− 5·59	8·49
588	Sept. 10·43	28	191	9·70	232	8·41	− 0·23	8·99
589	Oct. 7·71	27	17	9·77	7	8·99	+ 4·27	9·54
590	Nov. 4·00	27	20	7·18	12	9·85	+ 0·87	8·17
591	Dec. 1·32	28	760	10·29	38	15·03	+ 9·09	10·51

TABLE IV.

Year.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
1889	360	5·0	+ 7·26°	73·0	−11·90°	−10·68°	11·61°
1890	361	53·1	+22·20	46·3	−21·75	+ 1·73	21·99
1891	363	401	+20·49	169	−19·91	+ 8·52	20·31
1892	362	607	+15·09	607	−21·69	− 3·29	18·39
1893	360	517	+14·91	941	−14·26	− 3·93	14·49
1894	364	543	+12·31	739	−15·56	− 3·75	14·18
1895	364	565	+14·26	409	−12·54	+ 3·01	13·54
1896	364	203	+13·60	340	−14·77	− 4·15	14·33
1897	364	196	+ 8·32	318	− 7·73	− 1·62	7·96

The principal features of the record for 1897 are:

(1) There has been a decrease in mean daily spotted area as compared with 1896, but only to a very small extent; 5 per cent., as compared with the decrease of 44 per cent. of 1896 on the record for 1895. The rapidity of the decline which set in after 1893 seems therefore to have experienced a check.

(2) The umbræ, like the spots, have shown scarcely any decrease; in fact, only 2 per cent.

(3) The decrease in the faculæ, on the other hand, has been considerable; over 18 per cent.

(4) The decline in the spots has been nearly in the same proportion in both hemispheres.

(5) On the whole, therefore, the predominance in spot activity has rested, as in 1896, with the southern hemisphere.

(6) But the chief characteristic of 1897 has been the great decline in the mean distance of the spots from the equator. This had remained practically unaltered during the four preceding years, at about 14°. The mean distance in 1897 is not quite 8°. This circumstance, taken by itself, would suggest, if the precedents of the minima of 1878 and 1889 are followed, that the minimum has nearly been reached. The continuance of so considerable a mean daily spotted area becomes, therefore, in this connection most remarkable.

(7) The number of days without spots has increased considerably in 1897, being 32 as against 8 in 1896. The days without faculæ have remained the same—viz. 7.

(8) The decline in latitude has been irregular in both hemispheres. In the northern hemisphere the decline was very great during the first half of the year, and was accompanied with a great decrease in spots. A secondary revival both in area and latitude ensued, followed in its turn by another decline, and another revival was setting in in the last month of the year. In the southern hemisphere there was a similar movement in latitude, but rather less pronounced and more irregular; and the declines and revivals in latitude were not so strikingly synchronous with the declines and revivals in area.

Some remarks as to the Sun-spots of the present year may be added here to the above summary of results for 1897.

The last rotation in 1897—December 1–28—had been noteworthy for the appearance of a very fine group in the northern hemisphere, following upon a period of two complete synodic rotations, during which the solar activity had been very slight indeed, no single day showing a total spotted area of 150 (expressed, as usual, in millionths of the Sun's visible hemisphere),

whilst 14 days out of the 56 showed the Sun's disc wholly free from spots. During the appearance of this group—December 7–19—the mean daily spotted area of the Sun rose to 1390, practically equal to that of the years of maximum. After the disappearance of this group the spot activity remained fairly steady for the next two and a half months, a group which showed a considerable development running its course from February 8 to 20. This was the second appearance of a group which had formed near the centre of the disc on January 18, and which had shown some increase before it had reached the west limb on January 28. A series of minor magnetic disturbances continuously from January 15 to 21 accompanied the first appearance of this group. It made a third appearance, March 7–18, when it was accompanied by two fine groups, one to the north, the other south preceding. The latter, which was a very large group, crossed the central meridian on March 11, 12^h Greenwich civil time. These groups again raised the mean daily area for the period March 6–18 to 1390. After these groups had passed out of view at the west limb, no fresh outburst of importance occurred until August. A large magnetic disturbance and brilliant aurora occurred on March 15. The following table gives the mean daily areas for whole spots for the first nine rotations of 1898, so far as means are yet at hand for determining them :—

Table V.

No. of Rotation	Date of Commencement of each Rotation	No. of Days on which Photographs were taken	Mean of Daily Areas. Whole Spots
	d		
593	1897 December 28·64	26	435
594	1898 January 24·98	28	526
595	February 21·32	25	787
596	March 20·64	27	157
597	April 16·92	27	229
598	May 14·16	28	114
599	June 10·36	24	47
600	July 7·56	18	210
601	August 3·77	19	296
Mean for the period 1897 December 28–August 31		222	315

Up to the end of August, therefore, in spite of the activity in March, and the two less important revivals in February and at the beginning of August, the mean daily area had fallen markedly below that for 1897. But quite a new period set in with the appearance of a very fine group on the east limb on September 3. Table VI. exhibits the principal facts respecting this group during its first apparition, September 3–15 :—

TABLE VI.

Date 1898		Area of Whole Spots: Entire Disc	Entire Group	Chief Spot	Hel. Co-ordinates of Chief Spot: Longitude	Latitude	Length of Group
	d				°	°	°
September	3·438	1144	1014	956	240·9	−12·6	5
	4·476	1218	1092	1033	240·6	−12·6	
	5·649	1149	1041	1004	240 6	−12·3	
	6·428	1228	1123	1006	240·6	−12·1	12
	7·648	1444	1369	1120	240·2	−12·1	14
	8·480	1782	1782	1148	241·1	−12·6	16
	9·624	2021	2021	1169	241·3	−12·1	17
	10·444	2243	2235	1150	240·8	−12·6	18
	11·435	2201	2201	1131	241·3	−12·8	18
	12·477	1830	1830	1090	241·6	−13·1	17
	13·628	1912	1912	1123	241·6	−12·8	18
	14·433	2089	1968	1615	240·7	−12·3	16
	15·441	874	597	271	240·6	−13·6	

The mean daily area for this period, September 3–15, was therefore 1626, and was almost entirely due to the one group, which of itself gave a mean daily area of 1553.

The group crossed the central meridian on September 9, and attained its greatest development on September 10. At first the group had consisted almost entirely of the chief spot, but by September 7 a considerable stream of smaller spots had formed behind it. These increased in area on the succeeding days up to September 10, the chief spot varying very little in size. After September 10 the spots in the middle of the following stream began to disappear, and the group was interrupted by a broad gap. The development of the smaller following spots caused a rapid increase in the length of the group from September 3 to 10, after which there was a slight decline. The maximum length of the group was 135,000 miles on September 10. A great magnetic disturbance, with a brilliant aurora, occurred on September 9, when this group crossed the central meridian.

The group returned to the east limb on September 29, but had considerably diminished in size; it crossed the central meridian on October 6, and reached the west limb on October 12. It appeared at the east limb for the third time on October 27, a single spot of area about 70.

Advantage was taken of the first appearance of so fine a group to make some experiments with the 26-inch Thompson photographic equatorial. A negative enlarger was employed in the telescope, giving an image of the Sun on a scale of 29 inches to the solar diameter. After exposing a number of plates in order to find the focus, two were secured, one on September 11,

the other on September 14, that are nearly in the correct focus, and which show a considerable amount of fine detail. Some difficulty was experienced with the Thornton-Pickard exposing shutter, which has not yet been entirely overcome.

Since the appearance of the great group, September 3–15, several other groups of smaller, but still very considerable dimensions, have been seen, so that the present revival of activity has been by no means confined to a single group. The two principal passed the central meridian on October 28 and November 5 respectively.

The figures given for 1898 are approximate only.

Observations of Planet (433) (1898 D Q) *made at the Royal Observatory, Greenwich, with the 30-inch Reflector of the Thompson Equatorial.*

(*Communicated by the Astronomer Royal.*)

Photographs of Planet D Q were obtained with the 30-inch reflector of the Thompson Equatorial by Mr. Davidson on 1898 September 20, September 21, September 23, October 3 and November 3. An attempt was made on November 1 to obtain a photograph with the Astrographic Equatorial, but nothing was shown with an exposure of 12^m, presumably because the planet's motion was so rapid (being about $50''$ an hour).

The exposures given were 20^m on September 20, 20^m on September 21, 15^m on September 23, two exposures of 10^m and 5^m on October 3, and an exposure of 20^m on November 3.

On account of the faintness of the planet (whose photographic magnitude is given by Professor Pickering as $12^m{\cdot}7$ about the middle of September) the reflector was used for these photographs as having more light grasping power than the 26-inch refractor, although the distortion of the field is greater.

In all the photographs the planet was photographed near the centre of the plate. Its position on the plate and those of from 14 to 16 comparison stars were measured in the duplex micrometer. As no *réseau* had been printed on the plates excepting on the plate of November 3, a plate on which a *réseau* had been printed was placed under the right hand microscope of the micrometer, and was used instead of a *réseau* on the plate.

The Right Ascensions and Declinations of the reference stars were taken from the Ottakring Zone Observations for the *Astronomische Gesellschaft Catalogue*, except in the case of B.D. $-5°$,5335 and B.D. $-5°$,5349, for which the positions were derived from the Karlsruhe Observations and the Radcliffe Catalogue. For B.D. $-6°$,5558, $-6°$,5567 and $-6°$,5568, the means of the Right Ascensions and Declinations given in the Ottakring Zones, the Radcliffe Catalogue for 1890, and the Karlsruhe Observations were taken.

Standard co-ordinates were computed from these, which were compared with the measures and linear corrections of the form $ax+by+c$ and $dx+ey+f$ deduced, as in the reduction of the measures for the Astrographic Catalogue. The values of the constants for the several plates are as follows :—

	a	b	c int.	d	e	f int.
Sept. 20	−·01232	+·01458	−0·1012	−·01606	−·01236	+0·8595
21	−·01227	+·01058	+0·1918	−·01130	−·01196	+0·4692
23	−·01254	+·01360	−0·4053	−·01461	−·01203	+0·5714
Oct. 3	−·01270	+·01504	−0·2479	−·01630	−·01238	+0·4729
Nov. 3	−·01253	+·01058	−0·8508	−·01081	−·01147	+0·5271

The values of c and f are arbitrary and depend on the R.A. and N.P.D. of the centre of the plate assumed in the computation of the "Standard Co-ordinates" of the stars. The unit in which c and f are expressed is a *réseau* interval, *i.e.* 5^{mm} representing $5'$.

When the quantities a, b, d, and e are corrected for differential refraction and aberration, the values of a and e should be equal (giving the scale value), and the values of b and $-d$ should be equal (giving the orientation of the plate). The following values of the differences $a-e$ and $b+d$, corrected for differential refraction and aberration, are found—

	$a-e$.	$b+d$.
Sept. 20	+·00076	−·00158
21	+·00041	−·00072
23	+·00020	−·00111
Oct. 3	+·00040	−·00126
Nov. 3	−·00034	−·00023

It is assumed that these discordances arise from distortion of the field, the want of exact symmetry in the grouping of the stars about the centre of the plate, and the distance of the centre of the plate from the optical centre of the field.

With the values of the constants given above, corrections of the form $ax+by+c$, $dx+ey+f$, have been applied to the measured co-ordinates of the stars. The following table exhibits the residual differences of the measured and calculated positions of the different stars on the four nights, September 20, September 21, September 23, and October 3.

B.D. No.	Mag.	Assumed R.A. 1898·0.	Apparent Corrections to Assumed R.A. Sept. 20.	Sept. 21.	Sept. 23.	Oct. 3.	Mean Corr.	Mean Residual.	Assumed N.P.D. 1898·0.	Apparent Corrections to Assumed N.P.D. Sept. 20.	Sept. 21.	Sept. 23.	Oct. 3.	Mean Corrs.	Mean Resid.
°		h m s	s	s	s	s	s	s	° ′ ″	″	″	″	″	″	″
−6 5538	9·3	20 32 50·93	...	...	0·00	+0·02	+0·01	...	96 16 31·7	...	...	−0·5	+0·7	+0·1	...
−5 5335	6·5	33 42·87	...	...	...	0·00	0·00	...	95 17 16·6	...	...	...	+0·6	+0·6	...
−6 5545	8·5	33 45·22	0·00	0·00	+ ·03	+ ·05	+0·02	±·020	96 30 57·9	+0·4	−0·2	+0·6	+0·1	+0·2	±·28
−6 5546	7·7	33 52·52	− ·05	− ·06	·00	+ ·02	−0·02	·033	96 33 1·2	+1·8	+0·8	+1·0	+0·6	+1·1	·40
−6 5550	8·9	34 46·13	− ·08	− ·04	− ·08	− ·07	−0·07	·013	96 12 22·6	−0·3	−0·2	−0·2	−0·5	−0·3	·10
−6 5552	9·0	34 48·75	...	− ·03	− ·02	− ·05	−0·03	...	96 9 28·3	...	−0·2	−0·1	−0·7	−0·3	...
−6 5551	9·5	34 48·82	+ ·04	+ ·12	+ ·06	...	+0·06	...	96 39 49·5	−0·8	−0·8	−0·9	...	−0·8	...
−6 5558	7·6	35 59·61	− ·02	− ·03	− ·01	+ ·01	−0·01	·013	96 21 38·2	+0·3	0·0	+0·3	−0·1	+0·1	·18
−7 5378	8·6	36 19·35	+ ·02	+ ·05	+ ·01	+ ·01	+0·02	·013	96 51 56·6	0·0	+0·3	−0·3	−0·6	−0·1	·30
−6 5560	9·3	36 33·45	+ ·09	+ ·13	+ ·11	+ ·07	+0·10	·020	96 14 15·5	−1·1	−0·9	−0·8	−1·0	−1·0	·10
−5 5349	7·8	37 6·33	− ·09	− ·12	− ·02	− ·04	−0·07	·038	95 39 38·2	+2·3	+1·1	+1·6	+1·3	+1·6	·38
−6 5564	8·9	37 33·33	− ·01	·00	− ·01	− ·01	−0·01	·003	96 43 55·7	+0·1	−0·2	−0·1	−0·1	−0·1	·08
−6 5566	8·6	37 59·34	+ ·01	− ·03	− ·04	− ·04	−0·03	·015	96 35 26·3	−1·1	−0·9	−0·3	−0·2	−0·6	·38
−6 5567	8·0	38 29·05	+ ·05	+ ·06	·00	− ·01	+0·03	·030	96 19 15·8	−0·3	0·0	+0·1	+0·3	0·0	·18
−6 5568	7·0	38 32·83	+ ·09	+ ·04	+ ·02	+ ·06	+0·05	·023	95 57 28·2	−1·1	−0·9	−1·4	−1·6	−1·3	·25
−6 5570	9·0	38 57·83	− ·03	− ·02	·00	+ ·02	−0·01	·018	96 10 27·7	+0·5	+1·4	+1·1	+1·2	+1·1	·25
−6 5573	8·1	39 50·98	·00	− ·09	− ·03	− ·05	−0·04	±·028	96 31 37·3	−0·5	+0·5	0·0	+0·2	+0·1	±·30

The means of the discordances, where there are four observations, are $\pm 0^s \cdot 0202$ and $\pm 0'' \cdot 245$.

The probable error of one determination is therefore

$$\pm 0^s \cdot 0202 \times \sqrt{\frac{4}{3}} \times \cdot 84 \text{ for the R.A.}$$

and

$$\pm 0'' \cdot 245 \times \sqrt{\frac{4}{3}} \times \cdot 84 \text{ for the N.P.D.}$$

i.e. the probable error of R.A. is $\pm 0^s \cdot 019$ and of N.P.D. $\pm 0'' \cdot 24$.

Two measures were made of each star and four of the planet DQ. Hence it follows that the probable error of the position of the planet would be

$$\pm 0^s \cdot 019 \times \frac{1}{\sqrt{2}} = \pm . 0^s \cdot 013 \text{ in R.A.}$$

and

$$\pm 0'' \cdot 24 \times \frac{1}{\sqrt{2}} = \pm . 0'' \cdot 17 \text{ in N.P.D.}$$

But as the planet was near the centre while the reference stars were distributed over the plate, it may be expected that the actual probable errors of the planet's position would be much smaller. These probable errors do not include the probable errors in the assumed places of the reference stars.

The following table gives the assumed places and residual differences of the reference stars used in the reduction of the photograph taken on November 3.

The assumed star places were taken from the Karlsruhe observations except for B.D. -5°,5452, which was taken from Schjellerup's Catalogue for 1865.

B.D.	No.	Mag.	Assumed R.A. 1898·0.	Apparent Corr. to Assumed R.A.	Assumed N P.D. 1898·0.	App Corr. to Assumed N.P.D.
			h m s	s	° ′ ″	″
−4	5332	8·0	20 55 48·75	+0·02	93 50 20·2	+1·9
−4	5337	7·3	56 19·52	−0·01	94 31 54·3	−1·7
−5	5440	8·0	56 30·25	+0·09	95 3 57·4	−0·2
−5	5452	9·1	59 23·33	−0·12	95 13 34·8	+0·2
−4	5355	7·0	21 0 10·96	+0·03	94 46 6·4	+0·1
−4	5371	8·0	3 44·03	0·00	94 13 5·4	+0·2
−4	5372	7·8	3 59·15	−0·02	94 18 24·3	−0·1

To the Right Ascension and North Polar Distance of the planet determined directly from the measures corrections to reduce a star in the position of the planet from mean to apparent place were applied, as in the computation of "Standard Coordinates," mean places of the stars were used.

The following table gives the Greenwich mean time, corre-

sponding to the middle of the exposure, the Right Ascension and North Polar Distance of the planet.

Date. G.M.T.				Apparent R.A.			Apparent N.P.D.			Log Δ.	Light Time.		Corr. for Parallax R.A.	Corr. for Parallax N.P.D.
1898.	h	m	s	h	m	s	°	′	″		m	s	s	″
Sept. 20	9	20	6	20	37	32·43	96	21	20·5	9·9400	7	14	+·08	−8·6
21	8	39	17		37	7·64		21	12·1	9·9430	7	17	+·01	−8·5
23	7	49	1		36	26·31		20	43·9	9·9492	7	23	−·07	−8·4
Oct. 3	7	58	14		35	59·45		13	59·3	9·9811	7	57	+·02	−7·8
Nov. 3	8	15	36	21	1	4·25	94	47	52·3	0·0747	9	51	+·16	−6·1

The resulting corrections to the Ephemeris given by Dr. Berberich in *Ast. Nach.* 3517 are :—

	R.A.	N.P.D.
	s	″
Sept. 20	+ 7·11	+ 9·1
21	+ 7·86	+ 9·9
23	+ 9·04	+10·5
Oct. 3	+16·94	+10·2

The accurate Ephemeris is not continued to November 3, the date of the last photograph.

An approximate ephemeris from October 4 is given by Dr. Berberich in *Ast. Nach.* 3521, the resulting corrections to which from the photograph on Nov. 3 are :—

	R.A.	N.P.D.
	s	′
Nov. 3	+ 52	− 0 6

Royal Observatory, Greenwich:
1898 *November* 8.

Observations of Comet i 1898 (Brooks), made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The following observations were made with the Great Equatorial (G. E.), aperture 28 inches, and the Sheepshanks Equatorial (S. E.), aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power of G. E. 485, and S. E. 55.

1898.	Greenwich Mean Solar Time. d h m s	Observer.	Instrument.	☌ − ✱ R.A. m s	Corr. for Refraction. s	Log. Factor of Parallax.	☌ − ✱ N.P.D. ′ ″	Corr. for Refraction. ″	Log. Factor of Parallax.	No. of Comps.	Apparent R.A. of ☌ h m s	Apparent N.P.D. of ☌ ° ′ ″	Comp. Star.
Oct.	31 6 41 48	L.	G. E.	+0 10.96	0.00	9.5839	−0 15.4	0.0	0.6689	3	...	...	*a*
	31 6 41 48	"	"	−0 12.31	0.00	9.5839	+0 7.8	0.0	0.6689	3	...	...	*b*
	31 6 47 15	"	"	−0 8.19	0.00	9.5892	−2 26.1	0.0	0.6747	5	17 7 42.88	59 14 43.4	*c*
	31 5 59 30	A. C.	S. E.	+1 48.81	0.00	9.5346	−0 24.2	0.0	0.6248	6	17 7 28.68	59 9 27.5	*d*
	31 7 50 11	C. D.	"	−0 39.89	0.00	9.6256	−4 10.0	−0.1	0.7383	3	17 8 0.67	59 21 45.6	*e*
	31 7 55 42	"	"	+0 10.78	−0.01	9.6271	+5 11.6	+0.2	0.7433	3	17 8 1.84	59 22 21.3	*e*
Nov.	1 6 49 37	G. B.	"	−1 20.45	0.00	9.5777	+0 26.6	0.0	0.6968	6	17 14 2.97	61 52 30.2	*f*
	3 6 46 2	A. C.	"	+0 1.67	0.00	9.5537	+4 25.7	+0.1	0.7285	1	17 24 54.92	66 45 36.8	*g*
	3 6 46 2	"	"	−1 59.12	0.00	9.5537	−2 3.0	0.0	0.7285	1	17 24 55.41	66 45 42.1	*h*
	3 7 6 52	H. F.	"	+0 5.49	−0.01	9.5713	+6 31.0	+0.1	0.7434	5	17 24 58.73	66 47 45.1	*g*
	3 7 6 52	"	"	−1 55.50	0.00	9.5713	−0 0.3	0.0	0.7434	5	17 24 59.03	66 47 44.8	*h*
	4 7 4 21	A. C.	"	−2 3.65	−0.01	9.5621	+7 23.2	+0.2	0.7550	1	17 29 36.28	69 3 38.0	*i*
	4 6 6 40	H. F.	"	−2 13.74	0.00	9.4963	+2 1.9	+0.1	0.7204	2	17 29 26.20	68 58 16.6	*i*
	4 6 40 43	G. B.	"	−2 9.32	−0.01	9.5414	+4 50.5	+0.1	0.7406	3	17 29 30.61	69 1 5.2	*i*
	6 5 40 58	H. F.	"	−0 36.84	0.00	9.4481	+2 37.1	+0.1	0.7402	6	17 37 25.82	73 7 11.0	*k*
	8 5 47 50	A. C.	"	+3 17.22	0.00	9.4541	−3 14.2	−0.1	0.7700	6	17 44 9.28	76 53 0.5	*l*
	10 5 36 20	"	"	+0 36.34	0.00	9.4333	+2 4.5	+0.1	0.7886	6	17 49 43.01	80 13 36.5	*m*

C

Notes.

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the Comet.

The initials L., A. C., C. D., H. F., and G. B. are those of Mr. Lewis, Mr. Crommelin, Mr. Davidson, Mr. Furner, and Mr. Bischlager respectively.

The following micrometric measures of the position angle and distance of the Comet from star c were made by L. with the Great Equatorial.

Greenwich Mean Solar Time.	Observed Position Angle.	Greenwich Mean Solar Time.	Observed Distance.
d h m s	° ′	d h m s	″
1898 Oct. 31 7 14 9	200 0	31 7 15 39	46·08
31 7 20 58	170 45	31 7 22 9	86·69

Assuming that the motion of the Comet in 48 minutes was $+13^{s}\cdot36$ in R.A. and $+321''\cdot1$ in N.P.D., it was found that these measures were best represented by the following position of the Comet relatively to the star at the mean of the four times.

Greenwich Mean Solar Time.	✱ − ✱ R.A.	Log. Factor of Parallax.	✱ − ✱ N.P.D.	Log. Factor of Parallax.	Apparent R.A. of ✱.	Apparent N.P.D. of ✱.
d h m s	m s		′ ″		h m s	° ′ ″
Oct. 31 7 18 14	+0 0·22	9·6114	+1 0·8	0·7060	17 7 51·29	59 18 10·3

The following are the corresponding computed position angles and distances at the four times.

Greenwich Mean Solar Time.	Corresponding Position Angle.	Greenwich Mean Solar Time.	Corresponding Distance.
d h m s	° ′	d h m s	″
Oct. 31 7 14 9	199 27	31 7 15 39	44·05
31 7 20 58	170 59	31 7 22 9	88·72

Comparison Stars.

	Star's Name.	Assumed R.A. 1898·0. h m s	Assumed N.P.D. 1898·0. ° ′ ″	Authority.
a	Anonymous	17 7 28	59 15	
b	Anonymous	17 7 52	59 14	
c	Lalande 31323	17 7 49·65	59 17 13·6	Equatorial Comparisons with Stars *d* and *e*, 1898 Nov. 8.
d	Lalande 31281	17 5 38·46	59 9 55·5	Paris, 21735; Leiden Astr. Gesell. Zones, 193,202.
e	B. D. + 30°, No. 2945	17 8 39·13	59 25 59·9	Bonn Observations, vol. vi., Leiden Astr. Gesell. Zones, 55.
f	W. B. (2) XVII. 376	17 15 21·88	61 52 8·2	Paris, 21958; Cambridge Astr. Gesell. Catalogue, 8136.
g	W. B. (2) XVII. 674–5	17 24 51·50	66 41 15·8	Berlin Astr. Gesell. Catalogue, 5993.
h	W. B. (2) XVII. 738	17 26 52·76	66 47 50·1	Paris, 22306; Berlin Astr. Gesell. Catalogue, 6010; with PM +ˢ·004 + ″·07.
i	Piazzi XVII. 163	17 31 38·09	68 56 19·7	Paris, 22413; Brussels, 7074; Greenwich Ten-year Catalogue (1880), 2769; Berlin Astr. Gesell. Catalogue, 6038; with PM +ˢ·003 + ″·02.
k	W. B. (2) XVII. 1177–8–9	17 38 0·65	73 4 38·7	Paris, 22605; Berlin Astr. Gesell. Catalogue, 6404.
l	B. D. + 13°, No. 3447	17 40 49·93	76 56 19·1	Rumker 17ʰ Nachtrag, Bonn Observations, vol. vi., Sj 6375.
m	W. B. XVII. 953	17 49 4·42	80 11 36·3	First Glasgow Catalogue, 4420; Paris Catalogue, 22965.

Notes.

The place of star *c* in Lalande's Catalogue is 30ˢ too small in R.A. and 31″ too small in N.P.D.
Rumker's R.A. of star *l* has been diminished by 1 sec. The R.A. of star *m* in Lalande's Catalogue is 1ᵐ too great.

The comet was also photographed on November 1 and November 3 with the 30-inch reflector of the Thompson Equatorial. The photographs were taken in the primary focus of the reflector, which has a focal length of 11 feet 3 inches, and an aperture of 30 inches. Two plates were exposed on each night, and three exposures made on each. On the first plate on November 1 the exposures were 300^s, 130^s, and 60^s; and on the second, 240^s, 180^s, and 125^s. On November 3 the exposures were 240^s, 207^s, and 120^s for the first plate, and 150^s, 120^s, and 95^s for the second. The image of the comet is approximately at the centre of the plate on the photographs taken on November 3, but on those taken on November 1 the comet is at a considerable distance from the centre, the approximate co-ordinates of the images (expressed in *réseau* intervals of $5^{mm}=5'$) being $x=18{\cdot}1$ $y=6{\cdot}5$ on the first plate, and $x=17{\cdot}9$ $y=12{\cdot}9$ on the second, the co-ordinates of the centre of the plates being $x=14{\cdot}0$ $y=14{\cdot}0$.

The positions of the two darker images of the comet on November 1 and of the three images on November 3, together with those of about six reference stars, referred to the lines of the *réseau*, were measured by different measurers in the micrometer in the same manner as the plates for the Astrographic Catalogue. Two measures were made of each image of the comet, and one of each image of the reference stars, and the means taken.

The right ascensions and declinations of the reference stars were taken from the *Astronomischen Gesellschaft Catalogues*, Cambridge and Berlin respectively. Standard co-ordinates were computed from these, which were compared with the measures and linear corrections of the form $ax+by+c$ and $dx+ey+f$ deduced as in the reduction of the measures for the Astrographic Catalogue. The values of the constants for the several plates are as follows:—

		a	*b*	Int. *c*	*d*	*e*	Int. *f*
Nov.	1 (1)	−·01197	−·01315	−·0819	+·01404	−·01291	−·2356
	1 (2)	−·01232	−·00760	+·2336	+·00924	−·01196	+·4835
	3 (1)	−·01320	−·01321	+·3888	+·01472	−·01281	+·1460
	3 (2)	−·01333	−·01867	+·7904	+·02040	−·01304	+·3608

The values of c and f are arbitrary, and depend on the R.A. and Dec. of the centre of the plates assumed in the computation of the "Standard Co-ordinates" of the stars. The unit in which a and f are expressed is the *réseau* interval, *i.e.* $5'$.

It should be noted that the photographs on November 3 were slightly out of focus, which may account to some extent for the change in the scale values a and e.

With the values of the constants given above, corrections of the form $ax+by+c$, $dx+ey+f$, have been applied to the measured co-ordinates of the stars and comet. The following table exhibits the residual differences of the measured and calculated positions of the different stars on the four plates:—

Places of Reference Stars used in deducing the Comet's place.

November 1.

Name.	Mag.	Assumed R.A. 1875·0.	Apparent Corr. to assumed R.A. Plate I.	Plate II.	Assumed Dec. 1875·0.	Apparent Corr. to Assumed Dec. Plate I.	Plate II.
		h m s	s	s	° ′ ″	″	″
B.D. +28·2709	9·1	17 12 4·76	+0·09	+0·11	+28 3 18·5	−0·6	−0·2
27·2786	9·0	17 13 10·10	−0·08	−0·10	27 50 31·3	+0·6	+0·6
28·2718	8·2	13 40·09	+0·01	−0·01	28 23 0·4	+0·2	−0·3
28·2720	8·8	13 56·57	−0·10	−0·13	28 32 30·3	−0·5	−0·2
27·2790	7·1	14 24·81	...	+0·01	27 24 52·0	...	+0·5
28·2722	7·1	14 27·38	+0·09	+0·14	28 9 21·8	+0·4	+0·2
27·2792	8·7	15 39·61	0·00	+0·01	27 39 22·2	0·0	−0·9
November 3.							
+22·3147	8·9	17 22 38·16	+0·06	+0·06	+22 53 30·1	−0·9	−0·5
23·3122	9·0	23 8·60	+0·03	+0·02	23 42 26·3	+0·2	+0·2
23·3123	[illegible]	23 53·93	+0·07	+0·07	23 19 55·6	−0·3	−0·8
22·3156	8·5	24 27·96	−0·07	−0·05	22 24 22·5	+0·9	+0·4
22·3158	7·7	25 12·56	+0·02	0·00	22 58 14·0	0·0	−0·2
23·3124	8·1	25 55·10	−0·07	−0·05	23 13 18·4	+0·3	+0·4

To the right ascensions and declinations of the comet determined directly from the photographs, corrections to reduce a star in the position of the comet from Mean Place 1875·0 to Apparent Place on the date of observation, were applied, as in the computation of "Standard Co-ordinates," the Mean Places of the stars for 1875·0 were used.

The following are the Apparent Places of the comet corresponding to the mean of the times of the exposures as deduced from the four photographs :—

Date.	G.M.T.	Apparent R.A.	Apparent Dec.	Log. Δ.	Corr. for Parallax. R.A.	Dec.
	h m s	h m s	° ′ ″		s	″
Nov. 1 (1)	7 55 2	17 14 21·22	+28 0 45·5	9·8479	+0·59	+8·1
1 (2)	8 42 8	14 32·97	27 55 39·6	9·8479	+0·59	+8·8
3 (1)	7 33 50	25 5·22	23 9 46·0	9·8720	+0·52	+7·8
3 (2)	7 46 23	25 7·78	23 8 32·2	9·8720	+0·53	+7·9

In order to examine the relative accuracy of the different instruments and methods of observation of the comet, the individual comparisons on October 31 have all been reduced to the same epoch, viz.—$6^h\ 30^m$ G.M.T., the assumed motion of the comet in 48 minutes being $+13^s{\cdot}36$ in R.A. and $+321''{\cdot}1$ in N.P.D. This motion has been derived from Ristenpart and Möller's Ephemeris (supplement to *Ast. Nach.* 3526), corrected by the observations on October 31 and November 1. The correction for parallax has been applied here, the assumed value of log. Δ being 9·8364, this value being derived from Ristenpart and Möller's Ephemeris.

1898. Greenwich Mean Solar Time. d h m s	Observer.	Instrument.	Method of Observation.	⊘ − ✱ R.A. Corrected for Refraction and Parallax. m s	⊘ − ✱ N.P.D. Corrected for Refraction and Parallax. ′ ″	Correction for Motion in R.A. s	Correction for Motion in N.P.D. ′ ″	Apparent R.A. of ⊘ Reduced to 6h 30m. h m s	Apparent N.P.D. of ⊘ Reduced to 6h 30m. ° ′ ″	Comp. Star.
Oct. 31 5 49 31	A. C.	S. E.	Cross-bar Micrometer	+1 45·79	−1 43·2	+11·27	+4 30·8	17 7 36·93	59 12 39·3	d
5 54 31	”	”	”	+1 48·49	−1 6·3	+ 9·88	+3 57·4	38·24	42·8	”
5 57 26	”	”	”	+1 48·99	−0 50·3	+ 9·06	+3 37·8	37·92	39·2	”
6 0 18	”	”	”	+1 48·79	−0 12·5	+ 8·27	+3 18·7	36·93	57·9	”
6 6 20	”	”	”	+1 51·85	+0 17·2	+ 6·59	+2 38·3	38·31	47·2	”
6 8 52	”	”	”	+1 51·94	+0 33·1	+ 5·88	+2 21·4	37·69	46·2	”
31 6 37 24	L.	G. E.	”	+0 10·34	−0 51·9	− 2·06	−0 49·5	...	...	a
6 43 33	”	”	”	+0 12·16	−0 3·9	− 3·77	−1 30·6	...	...	”
6 44 28	”	”	”	+0 12·03	−0 10·8	− 4·03	−1 36·8	...	...	”
6 37 24	”	”	”	−0 12·76	−0 26·1	− 2·06	−0 49·5	...	...	b
6 43 33	”	”	”	−0 11·54	+0 16·7	− 3·77	−1 30·6	...	...	”
6 44 28	”	”	”	−0 10·97	+0 12·4	− 4·03	−1 36·8	...	...	”
6 45 54	”	”	”	−0 7·99	−2 47·8	− 4·43	−1 46·4	38·65	35·3	c
6 46 36	”	”	”	−0 7·95	−2 34·2	− 4·62	−1 51·0	38·50	44·3	”
6 47 21	”	”	”	−0 7·37	−2 30·9	− 4·83	−1 56·1	38·87	42·5	”
6 47 57	”	”	”	−0 7·42	−2 27·6	− 5·00	−2 0·1	38·65	41·8	”
6 48 28	”	”	”	−0 7·38	−2 24·6	− 5·14	−2 3·5	38·55	41·4	”
31 7 48 39	C. D.	S. E.	”	−0 39·37	−4 25·3	−21·89	−8 46·1	39·30	44·3	e
7 50 5	”	”	”	−0 39·50	−4 15·1	−22·29	−8 55·7	38·77	44·9	”
7 51 50	”	”	”	−0 38·95	−4 13·8	−22·78	−9 7·5	38·83	34·4	”
7 54 51	”	”	”	+0 11·22	+4 56·3	−23·62	−9 27·6	38·67	38·2	c
7 55 44	”	”	”	+0 11·63	+5 9·5	−23·86	−9 33·5	38·84	45·5	”
7 56 32	”	”	”	+0 11·33	+5 5·1	−24·08	−9 38·9	38·32	35·7	”
31 7 18 14	L.	G. E.	Position angle Micrcmeter	+0 0·81	+0 53·4	−13·43	−5 22·6	17 7 38·45	59 12 40·3	”

The observations and photographs on November 1 and 3, and the observations on November 4 have been reduced in a similar manner to a common epoch, viz.—7^h 30^m on November 1, 7^h 0^m on November 3, and 6^h 40^m on November 4. The observations in this table have all been corrected for parallax, and the following little table gives the assumed values of log. Δ, and of the motion in each co-ordinate :—

Date.	Log. Δ.	Motion in R.A. in 48^m.	Motion in N.P.D. in 48^m.
		s	″
Nov. 1	9·8479	+11·98	+307·4
3	9·8720	+ 9·80	+279·6
4	9·8846	+ 8·82	+263·9

1898.	Greenwich Mean Solar Time.	Observer.	Instrument.	Method of Observation.	☄−★ R.A. Corrected for Refraction and Parallax.	☄−★ N.P.D. Corrected for Refraction and Parallax.	Correction for Motion in R.A.	Correction for Motion in N.P.D.	Apparent R.A. of ☄ Reduced to 7^h 30^m.	Apparent N.P.D. of ☄ Reduced to 7^h 30^m.	Comp. Star.
	d h m s				m s	′ ″	s	′ ″	h m s	° ′ ″	
Nov.	1 6 44 14	G. B.	S. E.	Cross-bar Micrometer	−1 21·16	+0 17·8	+11·42	+4 53·1	17 14 13·68	61 57 14·5	*f*
	6 46 23	,,		,,	−1 20·46	−0 9·6	+10·88	+4 39·3	13·84	56 33·3	,,
	6 48 33	,,		,,	−1 20·30	+0 1·5	+10·35	+4 25·5	13·47	30·6	,,
	6 50 43	,,		,,	−1 19·97	+0 16·6	+ 9·81	+4 11·6	13·26	31·8	,,
	6 52 52	,,		,,	−1 18·60	+0 40·8	+ 9·27	+3 57·9	14·09	42·3	,,
	6 55 0	,,		,,	−1 18·98	+0 50·0	+ 8·74	+3 44·1	13·18	37·7	,,
					☄ Apparent R.A. Corrected for Refraction and Parallax.	☄ Apparent N.P.D. Corrected for Refraction and Parallax.					
					h m s	° ′ ″					
	7 55 2		30-inch	Photograph	17 14 21·81	61 59 6·4	− 6·25	−2 40·3	17 14 15·56	61 56 26·1	
	8 42 8		,,	,,	17 14 33·56	62 4 11·6	−18·00	−7 41·9	15·56	29·7	

1898.	Greenwich Mean Solar Time	Observer.	Instrument.	Method of Observation.	☄ – ✱ R.A. Corrected for Refraction and Parallax.	☄ – ✱ N.P.D. Corrected for Refraction and Parallax.	Correction for Motion in R.A.	Correction for Motion in N.P.D.	Apparent R.A. of ☄ Reduced to 7h 0m	Apparent N.P.D. of ☄ Reduced to 7h 0m	Comp. Star.
	d h m s				m s	′ ″	s	′ ″	h m s	° ′ ″	
Nov.	3 6 46 2	A. C.	S. E.	Cross-bar Micrometer	+0 2·15	+4 18·6	+ 2·85	+1 21·4	17 24 58·25	66 46 51·0	*g*
	6 46 2	,,	,,	,,	−1 58·64	−2 10·2	+ 2·85	+1 21·4	58·74	56·3	*h*
	3 6 55 27	H. F.	,,	,,	+0 3·20	+5 10·8	+ 0·93	+0 26·5	57·38	46 48·3	*g*
	7 3 58	,,	,,	,,	+0 5·80	+5 46·9	− 0·81	−0 23·1	58·24	34·8	,,
	7 7 49	,,	,,	,,	+0 6·12	+6 44·8	− 1·60	−0 45·6	57·77	47 10·2	,,
	7 11 35	,,	,,	,,	+0 7·12	+7 3·4	− 2·36	−1 7·5	58·01	5·9	,,
	7 15 29	,,	,,	,,	+0 7·66	+7 27·2	− 3·16	−1 30·2	57·75	8·0	,,
	6 55 27	,,	,,	,,	−1 56·25	−1 8·1	+ 0·93	+0 26·5	59·21	3·5	*h*
	7 3 58	,,	,,	,,	−1 55·47	−0 32·0	− 0·81	−0 23·1	58·25	46 50·0	,,
	7 7 49	,,	,,	,,	−1 55·07	−0 7·8	− 1·60	−0 45·6	57·86	51·7	,,
	7 11 35	,,	,,	,,	−1 54·63	+0 29·4	− 2·36	−1 7·5	57·54	47 7·0	,,
	7 15 29	,,	,,	,,	−1 53·60	+0 40·1	− 3·16	−1 30·2	57·77	46 55·0	,,
					☄ Apparent R.A. Corrected for Refraction and Parallax.	☄ Apparent N.P.D. Corrected for Refraction and Parallax.					
					h m s	° ′ ″					
	3 7 33 50		30 inch	Photograph	17 25 5·74	66 50 6·2	− 6·91	−3 17·1	17 24 58·83	66 46 49·1	
	7 46 23		,,	,,	17 25 8·31	66 51 19·9	− 9·47	−4 30·2	58·84	49·7	

Greenwich Mean Solar Time.	Observer.	Instrument	Method of Observation.	☌ – ✱ R.A. Corrected for Refraction and Parallax.	☌ – ✱ N.P.D. Corrected for Refraction and Parallax.	Correction for Motion in R.A.	Correction for Motion in N.P.D.	Apparent R.A. of ☌ Reduced to 6h 40m.	Apparent N.P.D. of ☌ Reduced to 6h 40m.	Comp. Star.
1898. d h m s				m s	′ ″	s	′ ″	h m s	° ′ ″	
Nov. 4 5 41 17	H. F.	S. E.	Cross-bar Micrometer	−2 17·86	−0 19·5	+10·79	+5 22·8	17 29 32·87	69 1 17·9	*i*
6 32 3	"	"	"	−2 8·80	+4 9·6	+ 1·46	+0 43·8	32·60	8·0	"
4 6 36 56	G. B.	"	"	−2 11·09	+4 39·3	+ 0·56	+0 16·8	29·41	10·7	"
6 41 3	"	"	"	−2 9·83	+4 51·2	− 0·19	−0 5·8	29·92	0·0	"
6 44 10	"	"	"	−2 5·69	+4 39·7	− 0·77	−0 22·9	33·48	0 31·4	"
4 7 4 21	A. C.	"	"	−2 3·18	+7 16·0	− 4·48	−2 13·9	17 29 32·28	69 1 16·7	"

Royal Observatory, Greenwich;
1898 November 11.

Approximate Ephemeris of the part of the Leonid swarm through which the Earth passed in 1866. By G. Johnstone Stoney, D.Sc., F.R.S.

In view of the great value which will attach to observations of the *Leonid* stream in the open sky if they can be secured, and taking into consideration that the conditions will be more favourable in the coming season than they have been hitherto, Dr. Isaac Roberts, undeterred by the negative results which have been encountered in former seasons, has expressed his intention of making another attempt to photograph this excessively faint object by careful and prolonged exposure. To enable him and other astronomers to make this attempt, the following Ephemeris has been prepared of that portion of the meteoric stream through which the Earth passed in 1866.

The actual perturbations which have since 1866 affected that portion of the stream have been, during the last few months, computed, assuming Adams's orbit, under the direction of Dr. Downing, F.R.S., superintendent of the *Nautical Almanac*; and the application to Adams's orbit of the actual perturbations instead of only the average shift of the node, which was all that was known before, has made it possible to render this Ephemeris much more reliable than those which preceded it. This improvement is of importance, since the perturbations during the current revolution—that is, since 1866 November 13—have been abnormally large.

If the stream can be photographed, it will probably impress itself as a very faint and somewhat broad band crossing the field of view, presenting somewhat the appearance of the fainter portion of a comet's tail; and it is perhaps not quite impossible that the stream, now that it is approaching both the Sun and the Earth, and now that the place to look for it is more exactly known, might be seen with an opera glass by observers where the atmosphere is unusually clear. If seen at all, it would appear to them as an excessively faint and narrow thread of light.

The computations have been made by Mr. Wright, of the *Nautical Almanac* Office, and the cost of preparing the Ephemeris has, as on former occasions, been met by a grant from the Royal Society.

Approximate Ephemeris of the Leonids.

Greenwich Midnight.	Right Ascension.	Decl.	Log. of Dist. from Earth.	Greenwich Midnight.	Right Ascension.	Decl.	Log. of Dist. from Earth.
1899.	h m s	° ′		1899.	h m s	° ′	
Jan. 1	13 43 59	N 0 59	0·6807	Jan. 6	13 44 22	N 1 14	0·6687
2	13 44 5	1 2	0·6784	7	13 44 25	1 18	0·6663
3	13 44 10	1 5	0·6760	8	13 44 27	1 21	0·6638
4	13 44 14	1 8	0·6736	9	13 44 28	1 25	0·6613
5	13 44 18	1 11	0·6712	10	13 44 29	1 28	0·6587

Greenwich Midnight.	Right Ascension.	Decl.	Log. of Dist. from Earth.	Greenwich Midnight.	Right Ascension.	Decl.	Log. of Dist. from Earth.
1899.	h m s	° ′		1899.	h m s	° ′	
Jan. 11	13 44 28	N 1 32	0·6562	Feb. 18	13 30 34	N 5 52	0·5523
12	13 44 26	1 36	0·6536	19	13 29 46	6 2	0·5495
13	13 44 24	1 41	0·6510	20	13 28 58	6 12	0·5468
14	13 44 21	1 45	0·6485	21	13 28 8	6 22	0·5441
15	13 44 16	1 49	0·6459	22	13 27 16	6 33	0·5415
16	13 44 10	1 54	0·6432	23	13 26 22	6 44	0·5388
17	13 44 4	1 59	0·6406	24	13 25 27	6 54	0·5362
18	13 43 56	2 3	0·6380	25	13 24 30	7 5	0·5335
19	13 43 48	2 8	0·6353	[illegible]	13 23 32	7 16	0·5309
20	13 43 39	2 14	0·6326	27	13 22 32	7 27	0·5283
21	13 43 29	2 19	0·6299	[illegible]	13 21 31	7 39	0·5258
22	13 43 17	2 25	0·6272	Mar. 1	13 20 28	7 50	0·5233
23	13 43 5	2 30	0·6245	2	13 19 23	8 2	0·5208
24	13 42 52	2 36	0·6218	[illegible]	13 18 17	8 13	0·5184
25	13 42 37	2 42	0·6191	[illegible]	13 17 10	8 25	0·5159
26	13 42 22	2 48	0·6163	5	13 16 1	8 37	0·5135
27	13 42 5	2 54	0·6135	6	13 14 50	8 49	0·5112
28	13 41 47	3 0	0·6108	7	13 13 38	9 1	0·5088
29	13 41 28	3 7	0·6080	8	13 12 25	9 13	0·5065
30	13 41 7	3 14	0·6052	9	13 11 10	9 26	0·5043
31	13 40 46	3 21	0·6025	10	13 9 54	9 38	0·5021
Feb. 1	13 40 23	3 28	0·5997	11	13 8 36	9 50	0·4999
2	13 39 59	3 35	0·5969	12	13 7 17	10 3	0·4977
3	13 39 34	3 42	0·5941	13	13 5 57	10 16	0·4956
4	13 39 7	3 50	0·5913	14	13 4 35	10 28	0·4936
5	13 38 39	3 57	0·5885	15	13 3 11	10 41	0·4916
6	13 38 10	4 5	0·5857	16	13 1 46	10 54	0·4897
7	13 37 40	4 13	0·5828	17	13 0 20	11 7	0·4878
8	13 37 8	4 21	0·5800	18	12 58 53	11 20	0·4860
9	13 36 35	4 30	0·5772	19	12 57 24	11 33	0·4842
10	13 36 1	4 38	0·5744	20	12 55 54	11 46	0·4824
11	13 35 26	4 47	0·5717	21	12 54 23	11 58	0·4807
12	13 34 49	4 56	0·5689	[illegible]	12 52 51	12 11	0·4791
13	13 34 10	5 5	0·5661	23	12 51 18	12 24	0·4776
14	13 33 29	5 14	0·5633	24	12 49 44	12 37	0·4761
15	13 32 47	5 23	0·5605	25	12 48 9	12 50	0·4747
16	13 32 4	5 33	0·5577	26	12 46 33	13 3	0·4733
17	13 31 20	5 42	0·5550	27	12 44 55	13 15	0·4719

Greenwich Midnight.	Right Ascension.	Decl.	Log. of Dist. from Earth.	Greenwich Midnight.	Right Ascension.	Decl.	Log. of Dist. from Earth.
1899.	h m s	° ′		1899.	h m s	° ′	
Mar. 28	12 43 17	N 13 28	0·4707	Apr. 5	12 29 49	N 15 7	0·4630
29	12 41 38	13 41	0·4695	6	12 28 6	15 18	0·4623
30	12 39 59	13 53	0·4684	7	12 26 23	15 30	0·4617
31	12 38 19	14 6	0·4673	8	12 24 40	15 41	0·4611
Apr. 1	12 36 38	14 18	0·4663	9	12 22 56	15 53	0·4606
2	12 34 56	14 30	0·4654	10	12 21 12	16 4	0·4602
3	12 33 14	14 43	0·4645	11	12 19 28	16 15	0·4599
4	12 31 32	14 55	0·4637	12	12 17 43	N 16 26	0·4596

The South Temperate Current of Jupiter, and the Red Spot.
By A. Stanley Williams.

The south temperate current is remarkable above all the other surface currents of *Jupiter* for the uniformity of its motion. This current comprises within its limits the conspicuous belt south of the south equatorial belt, now very generally known as the south temperate belt, and it is from observations of the numerous and prominent spots, and other irregularities of this belt, that we derive most of our information respecting the velocity of its motion. The current, however, is not confined to the south temperate belt. On the north it reaches to the south equatorial belt, whilst on the south its limit varies somewhat from year to year, and even in the same year in different longitudes. Sometimes it extends so far south as to include the dark belt just south of the south temperate belt; whilst occasionally, the more swiftly moving southern current encroaches upon the south temperate current to such an extent that, in certain longitudes, at least, it actually touches the south edge of the south temperate belt. This latter condition occurred, for instance, in 1892, and again in the present year. I have recently made fresh determinations of the velocity of the south temperate current in the years 1881 and 1888, and the results are given below.

1881.

Towards the end of September of this year there was a conspicuous belt visible a little south of the south edge of the red spot, which belt* was not continuous, but ended abruptly in longitude 115°, and the time at which the end of the belt appeared to be in mid-transit was noted upon nine nights.

* It appears uncertain whether this belt is identical with the present south temperate belt, or with a belt just south of the latter. Its approximate latitude, from measures of two drawings, is—27½°. There was a broad, bright interval between the north edge of the belt and the south edge of the red spot.

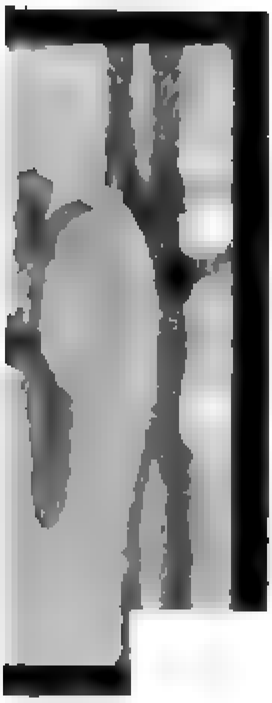


Fig. 1. May 2.

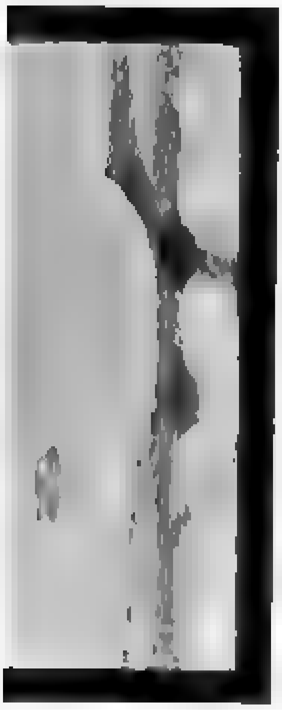


Fig. 2. May 10.

Fig. 3. May 14.

Fig. 4. May 24.

Fig. 5. June 10.

Fig. 6. June 17.

Fig. 7. July 18.

Fig. 8. June 18.

REGION OF THE RED SPOT ON JUPITER IN 1898.

These times were published in the *Observatory*, 1882, p. 112, but as the value of the period of rotation there given is not the correct sidereal period, I have re-discussed the results. The following table contains the observed times of transit of the end of the belt, the longitudes according to the late Mr. Marth's ephemeris in the *Monthly Notices*, vol. xli., p. 364,* and in the last column the residuals O – C, computed with a sidereal rotation period of $9^h\ 55^m\ 18^s{\cdot}3$, which satisfactorily represents the motion of the object.

Date. 1881.	G.M.T. of Transit. h. m.	Longitude. °	O – C. m.
Sept. 29	11 54	115·3	– 1·3
Oct. 1	13 32·5	115·9	+ 1·0
15	14 50	110·2	+ 0.8
26	8 43	104·4	– 1·8
30	11 58·5	104·8	+ 1·6
Nov. 15	14 51	98·0	+ 0·9
17	16 25	96·0	– 1·1
23	11 18	93·6	– 1·3
Dec. 1.	7 50	91·9	+ 1·1

The observations are very accordant, and show that the motion of the extremity of the belt was perfectly uniform.

1888.

In this year a very remarkable spot made its appearance at the preceding end of the red spot. It is remarkable, not only from its motion, which, as will be seen, was abnormal, but also from its curious appearance and its relationship to the red spot, so that a somewhat full description has been given of its appearance, and the changes that occurred in the course of the observations. As the changes of form might conceivably have affected the spot's apparent motion, it will be best to deal with this part of the subject first.

The first definite appearance of the marking dates from March 25, a drawing of this date showing a prominent dark mass on the sf. side of the red spot. Subsequent observations indicate the presence of much dark material about the south side of the last named object, until when we come to May 2 the appearance was that depicted in fig. 1, plate 1. It is noteworthy that at this time the sp. edge of the red spot was perfectly distinct and regular in outline, notwithstanding the dark markings in apparent contact with it. By May 10 the dark material at the sp. side of the red spot had drifted away from the latter, and now formed a distinct, isolated patch or spot, which was slightly reddish in tint (see fig. 2). Four days later the spot had already drifted a considerable distance farther from the red spot, thus early

* The rotation period of this ephemeris is $9^h\ 55^m\ 34^s{\cdot}47$.

giving indication of an abnormally rapid motion for a spot in this latitude, and had assumed the form of a very regular, well defined, oval spot (fig. 3). A narrow, well defined streak or belt apparently connected the spot with the red spot, and this streak was distinctly seen to cut off and *overlap* the south edge of the latter. This feature was perfectly well determined, for the north edge of the streak was quite sharp, straight, and well defined; whilst the curved outline of the red spot could be distinctly traced as far as the streak but no farther—the southern portion of the curve being cut off by the streak. On May 24 the spot was seen to have lengthened considerably, but its breadth had diminished (fig. 4). On this night again the dark streak or belt was seen distinctly to run in an uninterrupted straight line, and, apparently, to cut off the sudden portion of the red spot. On May 31 it was noted that the dark oval or elliptical spot was now darker in the middle than at the edges, and no reddish tinge could be distinguished. The breadth of the spot continued to decrease, so that by June 10 the marking had assumed the appearance shown in fig. 5, and it now preceded the red spot by a long interval. The spot now also diminished in length, so that by June 17 it was reduced to the dimensions shown in fig. 6. On July 6 it was described as being a mere vestige of what it had been, a mere blackish intensification of the narrow belt, which was visible preceding the spot as well as following it. By July 18 the spot had diminished to the size shown in fig. 7.

The following table contains, as before, the observed times of transit of the marking, the longitudes according to "System II" of Mr. Marth's ephemeris in the *Monthly Notices*, vol. xlviii., p. 68, and the residuals O − C. The third column gives the weights ascribed to the observations at the time, on a scale ranging from 1 (unsatisfactory) to 5 (perfect satisfaction).

Date. 1888.	G.M.T. of Transit. h m	W.	Longitude. °	O − C. m
May 14	13 13	3	306·4	−1·5
21	13 50	1	301·6	−0·2
24	11 20	2	302·1	+4·4
31	11 54	2	295·4	+2·5
June 10	9 52·5	3	285·6	−0·8
17	10 31	3	281·3	+1·1
22	9 28	4	274·7	−3·1
July 6	10 40	2	265·2	−5·5
18	10 24	2	255·3	−1·3
23	9 32	3	254·9	+4·5

The mean period of rotation of the spot, obtained by comparing the first four observations with the last two, is $9^h\ 55^m\ 8^s{\cdot}2 \pm 0^s{\cdot}40$, and this period appears to satisfactorily represent the

observations, although it is abnormally short, being just 10^s shorter than the average rotation period for this latitude. Since the marking was a long one and underwent great changes, it is conceivable that such changes might have given rise to a fictitious appearance of an unusually rapid drift. For instance, if the decrease in length took place at the f. end alone, the effect would be to make the spot's drift appear to be more rapid than really was the case. But even if the diminution in length had occurred in this manner, this would not nearly account for the whole of the observed difference. Moreover, the observations and drawings confirm the rapid drift, and also rather strongly give the impression of a uniform decrease in length at both ends. On May 31, when the middle of the spot appeared markedly darker than the edges, the darkest part was still at the centre of the marking. The observations of position also show that the motion of the object was uniform between May 14 and July 23, within the limits of ordinary observational errors, and this would disfavour the idea of the change occurring at one end only. It seems impossible therefore to regard the abnormally rapid drift of this spot as otherwise than real.

The remarkably abnormal nature of the motion of the spot will be more apparent if we compare the present determination with others. A list of the principal determinations of the rotation period of the s. temperate current was published in the *Monthly Notices*, vol. lvi., p. 149, and this list is repeated below, with the addition of the two results contained in the present paper.

	h m s s		
1787	R = 9 55 17·6	250*r*	Schrœter
1862	17·2	128*r*	Schmidt
1872–3	19·6 ± 2·34	...	O. Lohse
1880	16·2	...	Barnard
1880–1	17·9	...	Denning
1880–1	19·1	...	Barnard
1881	18·3 ± 0·20	152*r*	Williams
1887	18	55*d*	Terby
1887	17·1	3*s*	Williams
1888	8·2 ± 0·40	169*r*	„
1889	16·7 ± 0·33	263*r*	„
1889	19·0 ± 0·26	326*r*	„
1890–1	18·3	1296*r*	Denning
1891	18·2	53*r*	„
1891	20	2*s*	Hough

r = rotation ; *d* = days ; *s* = spots.

The foregoing list also shows clearly the remarkable uniformity in the velocity of this current. The simple mean of the

above values, excluding the 1888 result, is $9^h\ 55^m\ 18^s{\cdot}1$. In no case does an individual result differ by more than $1^s{\cdot}9$ from this mean, and as a difference of $1^s{\cdot}9$ in the period of rotation at the latitude of the s. temperate belt corresponds to a difference of 1·3 miles (2·1 kilometres) per hour in the velocity of the current, it follows that the motion of the s. temperate current has not varied by more than 1·3 miles per hour from its mean value during a period of 100 years, so far, of course, as the observations extend. And this small difference includes the observational errors and also local variations, excepting in the case of the second result of 1887. Such a degree of uniformity is, to say the least, very remarkable.

It is probable that the abnormal motion of 1888 was due to some local disturbance, and did not extend right round the planet. The observations of other spots in this latitude are not numerous enough, however, to give any certain information on this point, the considerable south declination of *Jupiter* in this year being very detrimental to obtaining accurate positions of the smaller and fainter spots.

The Red Spot.

Some observations bearing on the relationship of the red spot to a narrow dark streak or belt in 1888 have been detailed above. It may be added that the observations of May 14 and May 24 were both made under fairly satisfactory conditions with a power of 230 on my 6½ inch Calver reflector. On both nights the north edge of the dark streak was well defined, and appeared quite distinctly to cut off the southern part of the red spot. The observations were considered to be quite satisfactory at the time, and to be decisive on this point. Two conclusions may be drawn from this. One is that the streak, or at least the upper part of it, was situated at a higher level than the surface of the spot. The other is that the dark streak was composed of some actual material substance capable of concealing the spot, and was not merely a rift in the bright cloud envelope of the planet.

The last figure on plate 1 has been added on account of the unusual amount of detail shown about the red spot. Definition being good all the details shown were seen distinctly. These consist of a dark border to the sf. edge of the spot; a dark spot at the f. tip; another dark spot on the south edge of the red spot; and a white patch on the surface of the red spot. Rather curiously the dark spot on the south edge was joined to the belt on the south by a dark streak. The red spot was too far past transit when observations were commenced for its preceding half to be well seen.

Nomenclature of the Chief Surface Currents of Jupiter. By A. Stanley Williams.

The existence of a number of distinct surface currents upon the planet *Jupiter* is now very well known. In a paper published in the *Monthly Notices*, vol. lvi. p. 143, I enumerated nine such currents, most of which are permanent features of the planet. As it is often necessary to refer to the different currents, it is becoming increasingly desirable to have some simple designations by which to distinguish the most important of them. I therefore venture to suggest the following names.

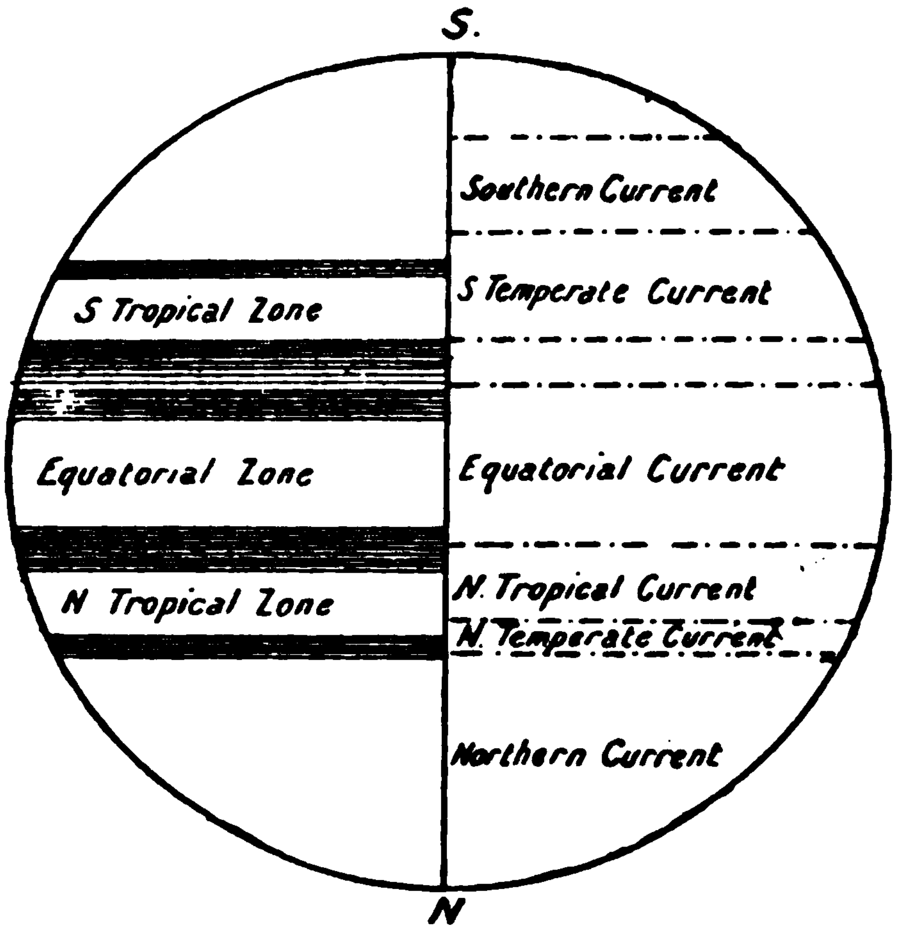
The most important current of all is undoubtedly the one occupying the equatorial regions of the planet. This is already well known as the *Equatorial Current*, V.*

To the north of this lies the current IV., and since this falls to a great extent in the bright north tropical zone, it might conveniently be termed the *North Tropical Current.*

Further north is the narrow but remarkable current III., which, from its connection with the north temperate belt, might well be called the *North Temperate Current.*

South of the equatorial belts we have the important current VIII., and as the south temperate belt is wholly included within its limits, this might be named the *South Temperate Current.*

The somewhat swifter current IX., which lies south of the last one, might be called the *Southern Current.*



The chief surface currents of *Jupiter*.

* The Roman numerals are those affixed to the different currents in the paper above referred to.

The accompanying diagram will illustrate clearly the nomenclature here proposed. One half of the diagram shows the positions of the more important and permanent belts, whilst on the other half the approximate limits of the chief currents are indicated, with the suggested names.

The boundaries or limits of some of the currents vary, however, from time to time with respect to the belts, so that they

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Ephemeris for Physical Observations of

Greenwich Noon.		P	L−O	B	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d	Q.	B′
1898.		°	°	°	″	″	″	°	°	°
Dec.	10	21·22	76·99	−2·92	32·89	0·14	30·84	7·49	291·12	−3·11
	12	21·13	77·35	2·93	33·03	·15	30·97	7·70	290·98	3·13
	14	21·05	77·70	2·94	33·17	·16	31·10	7·90	290·85	3·14
	16	20·96	78·05	2·96	33·31	·17	31·23	8·10	290·72	3·16
	18	20·88	78·39	2·97	33·46	·17	31·36	8·29	290·60	3·17
	20	20·80	78·72	−2·98	33·61	0·18	31·50	8·47	290·48	−3·18
	22	20·72	79·04	2·99	33·76	·19	31·64	8·64	290·36	3·19
	24	20·64	79·36	3·00	33·92	·20	31·79	8·80	290·25	3·20
	26	20·56	79·68	3·01	34·08	·21	31·94	8·97	290·14	3·21
	28	20·49	79·99	3·02	34·24	·22	32·09	9·13	290·03	3·22
	30	20·41	80·29	−3·03	34·41	0·23	32·25	9·28	289·93	−3·23
1899.										
Jan.	1	20·33	80·58	3·04	34·58	·24	32·41	9·42	289·82	3·24
	3	20·25	80·87	3·05	34·76	·24	32·58	9·55	289·71	3·25
	5	20·17	81·15	3·06	34·95	·25	32·75	9·68	289·60	3·26
	7	20·10	81·42	3·07	35·14	·26	32·93	9·80	289·50	3·27
	9	20·03	81·68	−3·08	35·33	0·26	33·11	9·91	289·39	−3·29
	11	19·96	81·92	3·09	35·52	·27	33·29	10·00	289·29	3·30
	13	19·90	82·16	3·10	35·71	·27	33·48	10·09	289·19	3·31
	15	19·84	82·39	3·11	35·91	·28	33·67	10·17	289·09	3·32
	17	19·78	82·61	3·12	36·11	·28	33·86	10·24	289·00	3·33
	19	19·72	82·83	−3·13	36·32	0·29	34·05	10·30	288·91	−3·34
	21	19·66	83·03	3·14	36·54	·29	34·25	10·35	288·82	3·35
	23	19·60	83·22	3·15	36·76	·30	34·45	10·39	288·73	3·36
	25	19·55	83·40	3·16	36·98	·30	34·66	10·42	288·64	3·37
	27	19·50	83·57	3·17	37·20	·30	34·87	10·44	288·55	3·38
	29	19·46	83·73	−3·17	37·43	0·31	35·08	10·44	288·47	−3·38
	31	19·42	83·88	−3·18	37·66	0·31	35·30	10·44	288·39	−3·39

may not always correspond exactly with the positions indicated on the diagram. The northern limit of the great equatorial current, for instance, is sometimes at the south edge of the north equatorial belt. But in 1898 the northern boundary was just north of the north equatorial belt, the whole of this belt being included within the equatorial current.

Jupiter, 1898–99. By A. C. D. Crommelin.

Greenwich Noon.		Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II	Corr. for Phase.	Light-time	A−O	B
1898.		°	°	°	m	°	°
Dec.	10	153·74	241·19	+0·24	50·63	69·486	−2·875
	12	109·31	181·50	·26	50·42	69·638	2·878
	14	64·88	121·81	·27	50·21	69·789	2·880
	16	20·46	62·13	·29	50·00	69·941	2·883
	18	336·06	2·46	·30	49·78	70·092	2·886
	20	291·66	302·81	+0·31	49·56	70·243	−2·889
	22	247·27	243·16	·33	49·34	70·395	2·892
	24	202·89	183·52	·34	49·11	70·547	2·895
	26	158·51	123·88	·35	48·88	70·698	2·897
	28	114·14	64·25	·36	48·65	70·850	2·899
	30	69·79	4·63	+0·38	48·41	71·002	−2·902
1899.							
Jan.	1	25·45	305·03	·39	48·16	71·154	2·904
	3	341·12	245·43	·40	47·91	71·305	2·907
	5	296·79	185·84	·41	47·66	71·457	2·909
	7	252·47	126·26	·42	47·41	71·608	2·912
	9	208·17	66·70	+0·43	47·15	71·759	−2·915
	11	163·89	7·16	·44	46·89	71·911	2·917
	13	119·61	307·62	·45	46·63	72·063	2·920
	15	75·33	248·08	·45	46·37	72·214	2·922
	17	31·07	188·56	·46	46·11	72·366	2·925
	19	346·81	129·04	+0·46	45·85	72·517	−2·928
	21	302·58	69·54	·47	45·58	72·669	2·930
	23	258·35	10·05	·47	45·31	72·820	2·933
	25	214·14	310·58	·47	45·04	72·972	2·935
	27	169·93	251·11	·47	44·77	73·124	2·937
	29	125·73	191·65	+0·47	44·50	73·276	−2·940
	31	81·55	132·21	+0·47	44·23	73·428	−2·942

Greenwich Noon.		P	L−O	B	Apparent Diameter. E. nat. 2r.	Defect.	Polar 2λ	ε	Q.	B′
1899.		°	°	°	″	″	″	°	°	°
Feb.	2	19.38	84.02	−3.19	37.89	0.31	35.52	10.43	288.32	−3.40
	[illegible]	19.34	84.15	3.20	38.12	.31	35.74	10.41	288.25	3.41
	6	19.31	84.26	3.20	38.36	.31	35.96	10.37	[illegible]	3.42
	8	19.28	84.36	−3.21	38.60	0.31	36.18	10.32	288.11	−3.43
	10	19.25	84.45	3.22	38.84	.31	36.40	10.25	288.04	3.44
	12	19.23	84.53	3.23	39.08	.31	36.63	10.18	287.97	3.45
	14	19.21	84.59	3.24	39.32	.30	36.86	10.09	287.90	3.46
	16	19.20	84.64	3.25	39.57	.30	37.09	9.99	287.84	3.47
	18	19.19	84.68	−3.26	39.81	0.29	37.32	9.88	287.77	−3.48
	20	19.19	84.71	3.27	40.05	.29	37.55	9.75	287.71	3.49
	22	19.18	84.73	3.28	40.29	.28	37.77	9.62	287.64	3.50
	24	19.18	84.73	3.29	40.53	.27	37.99	9.47	287.58	3.51
	26	19.18	84.72	3.29	40.77	.27	38.22	9.31	287.51	3.51
	28	19.19	84.70	−3.30	41.01	0.26	38.44	9.14	287.45	−3.52
Mar.	2	19.19	84.67	3.30	41.25	.25	38.66	8.96	287.39	3.52
	4	19.20	84.62	3.31	41.49	.24	38.88	8.76	287.33	3.53
	6	19.22	84.56	3.31	41.72	.23	39.10	8.55	287.27	3.53
	8	19.24	84.49	3.31	41.95	.22	39.32	8.33	287.21	3.53
	10	19.26	84.40	−3.32	42.17	0.21	39.53	8.09	287.15	−3.54
	12	19.29	84.30	3.32	42.39	.20	39.74	7.83	287.08	3.54
	14	19.32	84.19	3.32	42.61	.19	39.94	7.57	287.01	3.54
	16	19.35	84.07	3.32	42.82	.17	40.13	7.30	286.93	3.54
	18	19.39	83.94	3.33	43.02	.16	40.32	7.02	286.85	3.55
	20	19.43	83.80	−3.33	43.22	0.15	40.51	6.73	286.76	−3.55
	22	19.47	83.65	3.33	43.41	.13	40.69	6.43	286.66	3.55
	24	19.51	83.49	3.33	43.59	.12	40.86	6.11	286.53	3.55
	26	19.56	83.31	3.33	43.77	.11	41.03	5.78	286.40	3.55
	28	19.61	83.13	3.33	43.94	.10	41.19	5.45	286.26	3.55
	30	19.66	82.94	−3.33	44.10	0.09	41.34	5.12	286.10	−3.55
Apr.	1	19.72	82.75	3.33	44.25	.08	41.48	4.78	285.90	3.55
	3	19.78	82.54	3.33	44.40	.07	41.61	4.42	285.64	3.55
	5	19.84	82.32	3.33	44.54	.06	41.74	4.05	285.3	3.55
	7	19.90	82.10	3.33	44.67	.05	41.86	3.68	284.8	3.55
	9	19.97	81.87	−3.32	44.78	0.04	41.97	3.29	284.3	−3.54
	11	20.03	81.64	3.32	44.88	.03	42.06	2.91	283.7	3.54
	13	20.09	81.40	3.32	44.96	.02	42.14	2.52	283.0	3.54
	15	20.16	81.16	3.32	45.03	.02	42.21	2.13	281.9	3.54
	17	20.23	80.90	−3.31	45.09	0.01	42.27	1.72	280.3	−3.53

Greenwich Noon.	Longitude of ♃'s Central Meridian. 877°·00 I.	870°·27 II.	Corr. for Phase.	Light-time.	A−O	B
1899.	°	°	°	m	°	°
Feb. 2	37·37	72·77	+0·47	43·96	73·579	−2·945
4	353·21	13·34	·47	43·69	73·731	2·947
6	309·07	313·94	·47	43·42	73·883	2·949
8	264·93	254·54	+0·46	43·15	74·035	−2·951
10	220·81	195·15	·46	42·88	74·186	2·953
12	176·68	135·77	·45	42·62	74·338	2·956
14	132·58	76·41	·44	42·36	74·489	2·958
16	88·49	17·05	·44	42·10	74·641	2·960
18	44·41	317·71	+0·43	41·84	74·793	−2·962
20	0·33	258·37	·42	41·59	74·945	2·964
22	316·26	199·04	·40	41·34	75·096	2·966
24	272·22	139·73	·39	41·09	75·248	2·968
26	228·17	80·43	·38	40·85	75·400	2·970
28	184·14	21·13	+0·37	40·61	75·552	−2·972
Mar. 2	140·11	321·84	·35	40·38	75·704	2·974
4	96·10	262·57	·33	40·15	75·856	2·976
6	52·09	203·31	·32	39·93	76·009	2·978
8	8·10	144·05	·30	39·71	76·161	2·980
10	324·12	84·81	+0·28	39·50	76·313	−2·982
12	280·14	25·57	·27	39·29	76·465	2·984
14	236·18	326·34	·25	39·09	76·617	2·986
16	192·21	267·12	·23	38·90	76·769	2·988
18	148·25	207·90	·21	38·72	76·921	2·990
20	104·30	148·69	+0·19	38·54	77·073	−2·992
22	60·36	89·48	·18	38·37	77·225	2·994
24	16·41	30·28	·16	38·21	77·377	2·996
26	332·49	331·09	·14	38·05	77·530	2·998
28	288·56	271·90	·13	37·90	77·682	3·000
30	244·64	212·72	+0·12	37·76	77·834	−3·001
Apr. 1	200·71	153·53	·11	37·63	77·986	3·003
3	156·79	94·35	·09	37·51	78·139	3·004
5	112·88	35·17	·08	37·40	78·291	3·005
7	68·96	335·99	·06	37·30	78·443	3·006
9	25·04	276·82	+0·05	37·21	78·595	−3·008
11	341·13	217·64	·04	37·12	78·747	3·009
13	297·21	158·47	·03	37·05	78·899	3·011
15	253·29	99·28	·02	36·99	79·052	3·012
17	209·38	40·11	+0·01	36·94	79·204	−3·014

Greenwich Noon.		P	L − O	B	Apparent Diameter. Equat. 2r.	Defect.	Polar 2r.	d	Q	B′
1899.		°	°	°	″	″	″	°	°	°
Apr.	19	20·30	80·64	−3·31	45·15	0·01	42·32	1·32	277·4	−3·53
	21	20·36	80·39	3·31	45·20	·00	42·36	0·93	272·1	3·53
	23	20·42	80·13	3·30	45·23	·00	42·39	0·55	258·9	3·52
	25	20·48	79·87	3·30	45·24	·00	42·40	0·28	211·6	3·52
	27	20·54	79·61	3·29	45·24	[illegible]	42·40	0·45	157·9	3·51
	29	20·61	79·36	−3·28	45·23	0·00	42·39	0·80	128·9	−3·50
May	1	20·68	79·11	3·27	45·21	·00	42·37	1·19	122·4	3·49
	[illegible]	20·74	78·86	3·26	45·18	·01	42·34	1·59	119·2	3·48
	5	20·81	78·61	3·25	45·13	·01	42·30	1·98	117·2	3·47
	7	20·87	78·36	3·24	45·07	·02	42·25	2·39	116·0	3·46
	9	20·93	78·12	−3·23	45·00	0·03	42·18	2·78	115·0	−3·45
	11	20·99	77·89	3·22	44·92	[illegible]	42·10	3·16	114·40	3·43
	13	21·04	77·66	3·21	44·83	·04	42·02	3·54	113·98	3·42
	15	21·09	77·43	3·20	44·73	·05	41·93	3·92	113·60	3·41
	17	21·15	77·21	3·19	44·61	·06	41·82	4·29	113·22	3·40
	[illegible]	21·20	77·00	−3·18	44·49	0·07	41·70	4·65	112·90	−3·39
	21	21·25	76·79	3·17	44·36	[illegible]	41·58	5·01	112·64	3·38
	23	21·30	76·59	3·16	44·22	·09	41·45	5·36	112·45	3·37
	25	21·34	76·40	3·15	44·07	[illegible]	41·31	5·70	112·28	3·36
	27	21·38	76·22	3·14	43·91	·12	41·16	6·03	112·14	3·35
	29	21·42	76·04	−3·13	43·74	0·13	41·00	6·36	112·02	−3·34
	31	21·46	75·88	3·12	43·57	·15	40·84	6·68	111·91	3·33
June	2	21·49	75·73	3·11	43·39	·16	40·67	6·98	111·82	3·32
	4	21·52	75·59	3·09	43·20	·17	40·50	7·27	111·74	3·30
	6	21·55	75·47	3·08	43·00	·19	40·32	7·54	111·66	3·29
	8	21·58	75·35	−3·07	42·81	0·20	40·13	7·81	111·58	−3·27
	10	21·61	75·24	3·06	42·61	·21	39·93	8·07	111·51	3·26
	12	21·63	75·14	3·05	42·40	·22	39·73	8·33	111·44	3·25
	14	21·65	75·05	3·04	42·18	·23	39·53	8·57	111·38	3·24
	16	21·67	74·98	3·03	41·96	·24	39·33	8·79	111·32	3·23
	[illegible]	21·69	74·92	−3·02	41·74	0·26	39·12	9·00	111·26	−3·22
	20	21·70	74·88	3·01	41·52	·27	38·91	9·20	111·20	3·21
	22	21·71	74·85	3·00	41·29	·28	38·70	9·38	111·14	3·20
	24	21·72	74·83	2·99	41·06	[illegible]	38·49	9·55	111·08	3·19
	26	21·72	74·82	2·98	40·83	·29	38·28	9·71	111·03	3·18
	[illegible]	21·72	74·82	−2·97	40·59	0·30	38·06	9·86	110·98	−3·17
	30	21·71	74·83	2·97	40·36	·31	37·84	10·01	110·92	3·17
July	2	21·71	74·85	2·96	40·13	·32	37·62	10·14	110·88	3·16
	4	21·70	74·89	−2·95	39·90	0·32	37·40	10·25	110·82	−3·15

Greenwich Noon.	Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time	A–O	B
1899.	°	°	°	m	°	°
Apr. 19	165·46	340·94	+0·01	36·90	79·356	−3·016
21	121·54	281·75	·00	36·86	79·508	3·017
23	77·61	222·56	·00	36·84	79·660	3·019
25	33·67	163·37	·00	36·83	79·813	3·020
27	349·74	104·17	·00	36·82	79·965	3·021
29	305·78	44·96	−0·00	36·83	80·117	−3·023
May 1	261·83	345·74	·00	36·84	80·269	3·024
3	217·86	286·51	·01	36·87	80·422	3·026
5	173·89	227·28	·02	36·91	80·574	3·027
7	129·90	168·04	·02	36·96	80·727	3·029
9	85·91	108·78	−0·03	37·02	80·879	−3·030
11	41·89	49·51	·04	37·09	81·032	3·031
13	357·88	350·24	·05	37·16	81·185	3·033
15	313·86	290·96	·07	37·24	81·337	3·034
17	269·83	231·67	·08	37·33	81·489	3·035
19	225·77	172·35	−0·09	37·44	81·641	−3·036
21	181·71	113·03	·11	37·55	81·794	3·037
23	137·64	53·70	·12	37·67	81·946	3·038
25	93·55	354·35	·14	37·80	82·099	3·040
27	49·44	294·99	·16	37·94	82·252	3·041
29	5·34	235·62	−0·18	38·08	82·404	−3·042
31	321·21	176·23	·19	38·23	82·557	3·043
June 2	277·06	116·82	·21	38·39	82·709	3·044
4	232·90	57·40	·23	38·56	82·862	3·045
6	188·71	357·96	·25	38·73	83·014	3·046
8	144·52	298·51	−0·27	38·91	83·167	−3·046
10	100·32	239·05	·28	39·10	83·320	3·047
12	56·10	179·57	·30	39·29	83·473	3·048
14	11·87	120·08	·32	39·49	83·626	3·049
16	327·61	60·56	·33	39·70	83·779	3·050
18	283·34	1·04	−0·35	39·91	83·932	−3·051
20	239·05	301·48	·37	40·13	84·085	3·052
22	194·75	241·92	·38	40·35	84·237	3·053
24	150·43	182·35	·39	40·57	84·390	3·054
26	106·10	122·76	·41	40·80	84·542	3·054
28	61·76	63·16	−0·42	41·03	84·695	3·055
30	17·40	3·54	·44	41·27	84·848	3·056
July 2	333·04	303·92	·45	41·51	85·001	3·056
4	288·65	244·27	−0·46	41·75	85·154	−3·057

Greenwich Noon.	P	L−O	B	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	[illegible]	Q.	B'
1899. July 6	21·69	74·94	−2·94	39·67	0·33	37·18	10·36	110·78	−3·14
8	21·68	74·99	−2·94	39·44	0·33	36·96	10·46	110·73	−3·14
10	21·67	75·06	2·93	39·21	·33	36·75	10·54	110·67	3·13
12	21·65	75·14	2·92	38·98	·33	36·54	10·62	110·61	3·12
14	21·63	75·24	2·91	38·75	·34	36·32	10·67	110·55	3·11
16	21·61	75·35	2·91	38·52	·34	36·11	10·71	110·49	3·10
18	21·58	75·47	−2·90	38·30	0·34	35·90	10·75	110·43	−3·09
20	21·55	75·60	2·90	38·08	·34	35·69	10·77	110·37	3·09
22	21·52	75·73	2·89	37·86	·34	35·48	10·79	110·31	3·08
24	21·49	75·87	2·88	37·64	·33	35·28	10·81	110·25	3·07
26	21·45	76·03	2·87	37·42	·33	35·08	10·80	110·18	3·06
28	21·41	76·20	−2·87	37·21	0·33	34·88	10·78	110·11	−3·06
30	21·37	76·39	2·86	37·00	·33	34·68	10·75	110·04	3·05
Aug. 1	21·32	76·58	2·86	36·79	·32	34·48	10·71	109·97	3·05
3	21·27	76·78	2·85	36·58	·32	34·29	10·66	109·90	3·04
5	21·22	76·99	2·85	36·38	·31	34·10	10·61	109·82	3·04
7	21·17	77·20	−2·85	36·18	0·31	33·91	10·55	109·74	−3·04
9	21·12	77·42	2·85	35·98	·30	33·73	10·48	109·66	3·04
11	21·06	77·66	2·85	35·79	·29	33·55	10·40	109·58	3·04
13	21·00	77·91	2·84	35·60	·28	33·37	10·31	109·50	3·03
15	20·94	78·16	2·84	35·42	·28	33·20	10·20	109·42	3·03
17	20·88	78·42	−2·84	35·24	0·27	33·03	10·09	109·34	−3·03
19	20·81	78·69	2·84	35·07	·27	32·87	9·98	109·25	3·03
21	20·74	78·97	2·84	34·90	·26	32·71	9·85	109·16	3·03
23	20·68	79·26	2·84	34·73	·25	32·55	9·72	109·07	3·03
25	20·61	79·56	2·84	34·56	·24	32·39	9·57	108·98	3·03
27	20·53	79·86	−2·84	34·40	0·23	32·24	9·42	108·88	−3·03
29	20·45	80·17	2·84	34·24	·22	32·09	9·27	108·78	3·03
31	20·37	80·48	2·83	34·09	·21	31·95	9·11	108·68	3·02
Sept. 2	20·28	80·80	2·83	33·94	·21	31·81	8·94	108·57	3·02
4	20·19	81·13	2·83	33·79	·20	31·68	8·77	108·46	3·02
6	20·10	81·46	−2·83	33·65	0·19	31·55	8·59	108·34	−3·02
8	20·01	81·80	2·83	33·52	·18	31·42	8·41	108·21	3·02
10	19·92	82·14	2·83	33·39	·17	31·30	8·22	108·08	3·02
12	19·82	82·49	2·83	33·26	·16	31·18	8·02	107·95	3·02
14	19·72	82·85	2·83	33·14	·15	31·06	7·82	107·83	3·02
16	19·62	83·21	−2·83	33·02	0·15	30·95	7·61	107·70	−3·02
18	19·51	83·58	−2·83	32·90	0·14	30·84	7·39	107·56	−3·02

Greenwich Noon.	Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time.	A−O.	B
1899.	°	°	°	m	°	°
July 6	244·26	184·62	−·047	41·99	85·308	−3·058
8	199·86	124·96	−0·48	42·23	85·461	−3·059
10	155·44	65·28	·48	42·48	85·614	3·059
12	111·00	5·59	·49	42·73	85·767	3·060
14	66·55	305·88	·49	42·98	85·920	3·061
16	22·08	246·15	·50	43·24	86·073	3·061
18	337·61	186·42	−0·50	43·49	86·226	−3·062
20	293·12	126·68	·50	43·75	86·379	3·062
22	248·64	66·93	·50	44·00	86·532	3·063
24	204·15	7·18	·50	44·25	86·686	3·063
26	159·63	307·41	·50	44·51	86·839	3·063
28	115·11	247·63	−0·50	44·76	86·992	−3·064
30	70·56	187·82	·50	45·02	87·145	3·064
Aug. 1	26·01	128·01	·50	45·28	87·298	3·064
3	341·45	68·19	·50	45·54	87·452	3·065
5	296·89	8·37	·49	45·79	87·605	3·065
7	252·33	308·55	−0·49	46·04	87·758	−3·065
9	207·75	248·72	·48	46·29	87·912	3·065
11	163·16	188·87	·47	46·54	88·065	3·066
13	118·57	129·01	·46	46·78	88·219	3·066
15	73·97	69·16	·45	47·02	88·372	3·066
17	29·36	9·29	−0·44	47·26	88·525	−3·066
19	344·75	309·42	·43	47·50	88·679	3·067
21	300·12	249·53	·42	47·74	88·832	3·067
23	255·49	189·64	·41	47·97	88·986	3·067
25	210·85	129·75	·39	48·20	89·140	3·067
27	166·21	69·85	−0·38	48·43	89·293	−3·067
29	121·57	9·94	·37	48·65	89·447	3·068
31	76·92	310·04	·36	48·87	89·600	3·068
Sept. 2	32·27	250·13	·35	49·09	89·754	3·068
4	347·61	190·21	·34	49·30	89·908	3·068
6	302·96	130·30	−0·33	49·50	90·061	−3·068
8	258·30	70·38	·31	49·70	90·215	3·068
10	213·64	10·46	·30	49·89	90·368	3·068
12	168·97	310·54	·28	50·08	90·522	3·068
14	124·30	250·61	·27	50·26	90·675	3·068
16	79·63	190·68	−0·25	50·44	90·829	−3·067
18	34·95	130·74	−0·24	50·62	90·983	−3·067

The position of *Jupiter's* North Pole is assumed to be R.A. $17^h\ 51^m\ 58^s{\cdot}43$, N.P.D. $25^\circ\ 26'\ 22''{\cdot}7$ at the beginning of 1898, and R.A. $17^h\ 51^m\ 58^s{\cdot}69$, N.P.D. $25^\circ\ 26'\ 23''{\cdot}4$ at the beginning of 1899.

P denotes the position angle of the northern extremity of *Jupiter's* axis, reckoned eastward from the northernmost point of the disc.

$L-O+180^\circ$, $\Lambda-O+180^\circ$ are the jovicentric longitudes of the Earth and Sun respectively, reckoned in the plane of the planet's equator from O, the point of the vernal equinox of *Jupiter's* northern hemisphere; B, *B* are the jovicentric latitudes of the Earth and Sun above the planet's equator.

B′ is the jovigraphical latitude of the centre of the disc, and is obtained by increasing B by $\frac{1}{15}$ of itself.

The equatorial and polar diameters depend, as before, on Professor Barnard's measures, the assumed values at distance unity being $200''{\cdot}32$ and $187''{\cdot}75$ respectively.

The assumed time for light to traverse the unit distance is $498^s{\cdot}92$, this being the same value as that used by Mr. Marth.

d denotes the jovicentric angle between the Earth and Sun.

Q denotes the position angle of the point of greatest phase, and is reckoned eastward from the northernmost point of the disc. It also gives the position angle of the shadows of the satellites measured from the satellites themselves. I have substituted Q for the angle *w* tabulated in recent years, as probably more useful to most observers.

The longitudes of *Jupiter's* central meridian are computed with unaltered values of the rates of rotation and of the zero-meridians in the two adopted systems. The addition of the "Corr. for Phase" gives the longitudes of the meridians which bisect the illuminated disc. The great red spot will follow the zero-meridian of System II. by about 52^m at the beginning of this Ephemeris, and about 59^m at the end of it. (*Vide* Mr. Denning's paper, *Monthly Notices*, lviii. 9, p. 482.)

The zero meridian of System I. coincided in June and July last with No. 1 of Mr. Denning's list of equatorial spots (*Monthly Notices*, lviii. 9, p. 486).

The quantities in the Ephemeris are to be interpolated directly for the times for which they are required, the equation of light having been already applied.

The following is a list of Greenwich mean times when the adopted zero-meridians in the two systems will pass the middle of the illuminated disc.

System I.

G.M.T. 1898.	d	h	m	G.M.T. 1898.	d	h	m	G.M.T. 1898.	d	h	m	G.M.T. 1898.	d	h	m
Dec.	10	5	37·9	Dec.	11	21	0·2	Dec.	13	12	22·5	Dec.	15	3	44·8
		15	28·5		12	6	50·8			22	13·1			13	35·3
	11	1	19·1			16	41·4		14	8	3·7			23	25·9
		11	9·7		13	2	32·0			17	54·2		16	9	16·4

System I.

G.M.T. 1898.	d	h	m	G.M.T. 1899.	d	h	m	G.M.T. 1899.	d	h	m	G.M.T. 1899.	d	h	m
Dec.	16	19	7·0	Jan.	1	18	58·6	Jan.	17	18	49·3	Feb.	2	18	39·0
	17	4	57·6		2	4	49·2		[illegible]	4	39·8		3	4	29·4
		14	48·2			14	39·7			14	30·4			14	19·9
	18	0	38·8		3	0	30·3		19	0	20·9		4	0	10·4
		10	29·3			10	20·8			10	11·4			10	0·8
		20	19·9			20	11·4			20	1·9			19	51·3
	19	6	10·5		4	6	1·9		20	5	52·4		5	5	41·8
		16	1·0			15	52·5			15	42·9			15	32·3
	20	1	51·6		5	1	43·0		[illegible]	1	33·4		6	1	22·7
		11	42·2			11	33·6			11	23·9			11	13·2
		21	32·7			21	24·1			21	14·4			21	3·7
	21	7	23·3		6	7	14·7		22	7	4·9		7	6	54·2
		17	13·8			17	5·2			16	55·5			16	44·7
	22	3	4·4		7	2	55·7		23	2	46·0		8	2	35·2
		12	54·9			12	46·3			12	36·5			12	25·6
		22	45·5			22	36·8			22	27·0			22	16·1
	23	8	36·0		8	8	27·3		24	8	17·5		9	8	6·6
		18	26·6			18	17·8			18	8·0			17	57·1
	24	4	17·1		9	4	8·3		25	3	58·6		10	3	47·5
		14	7·7			13	58·9			13	49·1			13	38·0
		23	58·2			23	49·4			23	39·6			23	28·5
	25	9	48·8		10	9	39·9		26	9	30·1		11	9	19·0
		19	39·4			19	30·5			19	20·5			19	9·5
	26	5	29·9		11	5	21·0		27	5	11·0		12	4	59·9
		15	20·5			15	11·5			15	1·5			14	50·4
	27	1	11·1		12	1	2·0		28	0	52·0		13	0	40·9
		11	1·6			10	52·5			10	42·5			10	31·4
		20	52·2			20	43·0			20	33·0			20	21·8
	28	6	42·7		13	6	33·5		29	6	23·5		14	6	12·3
		16	33·3			16	24·1			16	14·0			16	2·8
	29	2	23·8		14	2	14·6		30	2	4·5		15	1	53·2
		12	14·3			12	5·1			11	55·0			11	43·7
		22	4·9			21	55·6			21	45·4			21	34·1
	30	7	55·4		15	7	46·1		31	7	35·9		16	7	24·6
		17	45·9			17	36·7			17	26·5			17	15·1
	31	3	36·5		16	3	27·2	Feb.	1	3	17·0		17	3	5·5
		13	27·0			13	17·7			13	7·5			12	55·9
		23	17·6			23	8·3			22	58·0			22	46·4
1899. Jan.	1	9	8·1		17	8	58·8		2	8	48·5		18	8	36·8

System I.

	G.M.T.				G.M.T.				G.M.T.				G.M.T.		
1899.	d	h	m	1899.	d	h	m	1899.	d	h	m	1899.	d	h	m
Feb.	18	18	27·3	Mar.	6	18	14·9	Mar.	22	18	1·5	Apr.	7	17	47·7
	19	4	17·8		7	4	5·3		23	3	52·0		8	3	38·1
		14	8·2			13	56·7			13	42·4			13	28·5
		23	58·7			23	46·1			23	32·8			23	18·9
	20	9	49·1		8	9	36·5		24	9	23·3		9	9	9·2
		19	39·5			19	27·0			19	13·7			18	59·7
	21	5	29·9		9	5	17·5		25	5	4·1		10	4	50·1
		15	20·3			15	7·9			14	54·5			14	40·5
	22	1	10·6		10	0	58·4		26	0	44·9		11	0	30·9
		11	1·1			10	48·8			10	35·3			10	21·3
		20	51·6			20	39·3			20	25·7			20	11·7
	23	6	42·1		11	6	29·7		27	6	16·2		12	6	2·1
		16	32·6			16	20·1			16	6·6			15	52·6
	24	2	23·2		12	2	10·6		28	1	57·0		13	1	43·0
		12	13·6			12	1·0			11	47·4			11	33·4
		22	4·1			21	51·4			21	37·8			21	23·8
	25	7	54·6		13	7	41·8		29	7	28·2		14	7	14·2
		17	45·1			17	32·3			17	18·6			17	4·6
	26	3	35·6		14	3	22·7		30	3	9·0		15	2	55·0
		13	26·0			13	13·1			12	59·4			12	45·4
		23	16·5			23	3·5			22	49·8			22	35·8
	27	9	6·9		15	8	54·0		31	8	40·2		16	8	26·2
		18	57·3			18	44·4			18	30·7			18	16·6
	28	4	47·8		16	4	34·8	Apr.	1	4	21·1		17	4	7·0
		14	38·2			14	25·2			14	11·5			13	57·4
Mar.	1	0	28·7		17	0	15·7		2	0	1·9			23	47·8
		10	19·1			10	6·1			9	53·2		18	9	38·2
		20	9·6			19	56·5			19	42·7			19	28·6
	2	6	0·1		18	5	46·9		3	5	33·1		19	5	19·0
		15	50·5			15	37·3			15	23·5			15	9·4
	3	1	40·9		19	1	27·8		4	1	13·9		20	0	59·8
		11	31·4			11	18·2			11	4·4			10	50·3
		21	21·8			21	8·6			20	54·8			20	40·7
	4	7	12·2		20	6	59·0		5	6	45·2		21	6	31·1
		17	2·7			16	49·5			16	35·6			16	21·5
	5	2	53·1		21	2	39·9		6	2	26·0		22	2	11·9
		12	43·6			12	30·3			12	16·5			12	2·3
		22	34·0			22	20·7			22	6·9			21	52·7
	6	8	24·5		22	8	11·1		7	7	57·3		23	7	43·1

System I.

	G.M.T.				G.M.T.				G.M.T.				G.M.T.		
1899.	d	h	m	1899.	d	h	m	1899.	d	h	m	1899.	d	h	m
Apr.	23	17	33.5	May	9	17	20.1	May	25	17	7.7	June	10	16	57.1
	24	3	23.9		10	3	10.5		26	2	58.2		11	2	47.6
		13	14.3			13	0.9			12	48.7			12	38.1
		23	4.7			22	51.3			22	39.1			22	28.6
	25	8	55.1		11	8	41.8		27	8	29.6		12	8	19.1
		18	45.6			18	32.2			18	20.1			18	9.6
	26	4	36.0		12	4	22.7		28	4	10.6		13	4	0.1
		14	26.4			14	13.1			14	1.1			13	50.6
	27	0	16.8		13	0	3.5			23	51.6			23	41.1
		10	7.2			9	54.0		29	9	42.1		14	9	31.6
		19	57.7			19	44.4			19	32.5			19	22.1
	28	5	48.1		14	5	34.9		30	5	23.0		15	5	12.6
		15	38.5			15	25.3			15	13.5			15	3.2
	29	1	29.0		15	1	15.8		31	1	4.0		16	0	53.7
		11	19.4			11	6.2			10	54.4			10	44.2
		21	9.8			20	56.7			20	44.9			20	34.8
	30	7	0.2		16	6	47.1	June	1	6	35.4		17	6	25.3
		16	50.6			16	37.6			16	25.9			16	15.8
May	1	2	41.0		17	2	28.0		2	2	16.4		18	2	6.4
		12	31.4			12	18.5			12	6.9			11	56.9
		22	21.9			22	8.9			21	57.4			21	47.4
	2	8	12.3		18	7	59.4		3	7	47.9		19	7	38.0
		18	2.7			17	49.8			17	38.4			17	28.5
	3	3	53.2		19	3	40.3		4	3	28.9		20	3	19.0
		13	43.6			13	30.7			13	19.4			13	9.6
		23	34.0			23	21.2			23	9.9			23	0.1
	4	9	24.4		20	9	11.6		5	9	0.4		21	8	50.6
		19	14.9			19	2.1			18	50.9			18	41.2
	5	5	5.3		21	4	52.6		6	4	41.3		22	4	31.7
		14	55.7			14	43.0			14	31.9			14	22.2
	6	0	46.1		22	0	33.5		7	0	22.4		23	0	12.8
		10	36.5			10	23.9			10	12.9			10	3.3
		20	26.9			20	14.4			20	3.4			19	53.9
	7	6	17.3		23	6	4.9		8	5	53.9		24	5	44.4
		16	7.8			15	55.3			15	44.5			15	34.9
	8	1	58.3		24	1	45.8		9	1	35.0		25	1	25.5
		11	48.7			11	36.2			11	25.5			11	16.0
		21	39.2			21	26.7			21	16.1			21	6.6
	9	7	29.6		25	7	17.2		10	7	6.6		26	6	57.1

System I.

1899.	d	h	m	1899.	d	h	m	1899.	d	h	m	1899.	d	h	m
June	26	16	47·7	July	12	16	39·8	July	28	16	33·2	Aug.	13	16	27·5
	27	2	38·3		13	2	30·4		29	2	23·8		14	2	18·2
		12	28·8			12	20·9			12	14·4			12	8·8
		22	19·4			22	11·5			22	5·0			21	59·4
	28	8	10·0		14	8	2·1		30	7	55·6		15	7	50·0
		18	0·5			17	52·7			17	46·2			17	40·7
	29	3	51·1		15	3	43·3		31	3	36·8		16	3	31·3
		13	41·7			13	33·9			13	27·4			13	21·9
		23	32·2			23	24·5			23	18·0			23	12·6
	30	9	22·8		16	9	15·1	Aug.	1	9	8·6		17	9	3·2
		19	13·4			19	5·7			18	59·2			18	53·8
July	1	5	3·9		17	4	56·3		2	4	49·9		18	4	44·5
		14	54·5			14	46·9			14	40·6			14	35·1
	2	0	45·0		18	0	37·6		3	0	31·3		19	0	25·7
		10	35·6			10	28·2			10	21·9			10	16·4
		20	26·1			20	18·8			20	12·5			20	7·0
	3	6	16·7		19	6	9·4		4	6	3·1		20	5	57·7
		16	7·2			16	0·0			15	53·8			15	48·3
	4	1	57·8		20	1	50·6		5	1	44·4		21	1	38·9
		11	48·4			11	41·2			11	35·0			11	29·6
		21	38·9			21	31·8			21	25·6			21	20·2
	5	7	29·5		21	7	22·4		6	7	16·2		22	7	10·9
		17	20·1			17	12·9			17	6·8			17	1·6
	6	3	10·7		22	3	3·5		7	2	57·4		23	2	52·2
		13	1·2			12	54·1			12	48·1			12	42·8
		22	51·8			22	44·7			22	38·7			22	33·5
	7	8	42·4		23	8	35·3		8	8	29·3		24	8	24·1
		18	32·9			18	25·9			18	19·9			18	14·8
	8	4	23·5		24	4	16·5		9	4	10·6		25	4	5·4
		14	14·0			14	7·1			14	1·2			13	56·0
	9	0	4·6			23	57·7			23	51·8			23	46·7
		9	55·2		25	9	48·3		10	9	42·5		26	9	37·3
		19	45·8			19	38·9			19	33·1			19	28·0
	10	5	36·4		26	5	29·5		11	5	23·8		27	5	18·6
		15	26·9			15	20·1			15	14·4			15	9·2
	11	1	17·5		27	1	10·7		12	1	5·0		28	0	59·9
		11	8·1			11	1·3			10	55·6			10	50·5
		20	58·6			20	51·9			20	46·3			20	41·1
	12	6	49·2		28	6	42·5		13	6	36·9		29	6	31·7

System I.

1899.	G.M.T. d	h	m	1899.	G.M.T. d	h	m	1899.	G.M.T. d	h	m	1899.	G.M.T. d	h	m
Aug.	29	16	22·4	Sept.	4	0	20·9	Sept.	8	22	28·7	Sept.	13	20	36·5
	30	2	13·1			10	11·6		9	8	19·4		14	6	27·1
		12	3·8			20	2·3			18	10·0			16	17·8
		21	54·4		5	5	52·9		10	4	0·7		15	2	8·4
	31	7	45·1			15	43·6			13	51·3			11	59·1
		17	35·8		6	1	34·3			23	41·9			21	49·8
Sept.	1	3	26·4			11	24·9		11	9	32·6		16	7	40·4
		13	17·0			21	15·6			19	23·2			17	31·1
		23	7·7		7	7	6·2		12	5	13·9		17	3	21·8
	2	8	58·3			16	56·8			15	4·5			13	12·4
		18	49·0		8	2	47·4		13	0	55·2			23	3·1
	3	4	39·6			12	38·1			10	45·8		18	8	53·8
		14	30·2												

System II.

1898.	G.M.T. d	h	m	1898.	G.M.T. d	h	m	1898.	G.M.T. d	h	m	1899.	G.M.T. d	h	m
Dec.	10	3	16·2	Dec.	20	1	34·1	Dec.	29	23	51·7	Jan.	8	22	9·0
		13	11·9			11	29·9		30	9	47·4		9	8	4·7
		23	7·7			21	25·6			19	43·1			18	0·4
	11	9	3·4		21	7	21·4		31	5	38·8		10	3	56·1
		18	59·2			17	17·1			15	34·6			13	51·7
	12	4	54·9		22	3	12·8	1899. Jan.	1	1	30·3			23	47·4
		14	50·6			13	8·6			11	26·0		11	9	43·1
	13	0	46·4			23	4·3			21	21·8			19	38·8
		10	42·2		23	9	0·0		2	7	17·5		12	5	34·5
		20	37·9			18	55·7			17	13·2			15	30·2
	14	6	33·7		24	4	51·5		3	3	8·9		13	1	25·9
		16	29·4			14	47·2			13	4·7			11	21·6
	15	2	25·2		25	0	43·0			23	0·4			21	17·3
		12	20·9			10	38·7		4	8	56·1		14	7	13·0
		22	16·7			20	34·4			18	51·8			17	8·7
	16	8	12·5		26	6	30·2		5	4	47·5		15	3	4·4
		18	8·2			16	25·9			14	43·2			13	0·1
	17	4	4·0		27	2	21·6		6	0	39·0			22	55·8
		13	59·7			12	17·4			10	34·7		16	8	51·5
		23	55·5			22	13·1			20	30·4			18	47·3
	18	9	51·2		28	8	8·8		7	6	26·2		17	4	43·0
		19	47·0			18	4·5			16	21·9			14	38·6
	19	5	42·7		29	4	0·2		8	2	17·6		18	0	34·3
		15	38·4			13	56·0			12	13·3			10	30·0

System II.

1899.	G.M.T. d	h	m	1899.	G.M.T. d	h	m	1899.	G.M.T. d	h	m	1899.	G.M.T. d	h	m
Jan.	18	20	25·7	Feb.	3	23	37·1	Feb.	20	2	47·4	Mar.	8	5	56·8
	19	6	21·4		4	9	32·8			12	43·0			15	52·4
		16	17·1			19	28·4			22	38·7		9	1	48·0
	20	2	12·8		5	5	24·1		21	8	34·3			11	43·6
		12	8·5			15	19·7			18	30·0			21	39·2
		22	4·2		6	1	15·4		22	4	25·6		10	7	34·9
	21	7	59·9			11	11·1			14	21·2			17	30·4
		17	55·6			21	6·7		23	0	16·9		11	3	26·0
	22	3	51·2		7	7	2·4			10	12·5			13	21·6
		13	46·9			16	58·0			20	8·1			23	17·1
		23	42·6		8	2	53·7		24	6	3·8		12	9	12·7
	23	9	38·3			12	49·4			15	59·4			19	8·3
		19	34·0			22	45·0		25	1	55·0		13	5	4·0
	24	5	29·6		9	8	40·7			11	50·6			14	59·6
		15	25·3			18	36·3			21	46·3		14	0	55·3
	25	1	21·0		10	4	32·0		26	7	41·9			10	50·9
		11	16·7			14	27·6			17	37·5			20	46·5
		21	12·4		11	0	23·3		27	3	33·1		15	6	42·1
	26	7	8·1			10	18·9			13	28·7			16	37·7
		17	3·8			20	14·6			23	24·4		16	2	33·3
	27	2	59·5		12	6	10·2		28	9	20·0			12	28·9
		12	55·1			16	5·8			19	15·6			22	24·5
		22	50·8		13	2	1·5	Mar.	1	5	11·2		17	8	20·1
	28	8	46·5			11	57·1			15	6·9			18	15·7
		18	42·1			21	52·8		2	1	2·5		18	4	11·3
	29	4	37·8		14	7	48·4			10	58·1			14	6·9
		14	33·4			17	44·1			20	53·8		19	0	2·5
	30	0	29·1		15	3	39·7		3	6	49·4			9	58·1
		10	24·7			13	35·4			16	45·0			19	53·7
		20	20·4			23	31·0		4	2	40·6		20	5	49·3
	31	6	16·0		16	9	26·7			12	36·2			15	44·9
		16	11·7			19	22·3			22	31·8		21	1	40·4
Feb.	1	2	7·4		17	5	18·0		5	8	27·4			11	36·0
		12	3·1			15	13·6			18	23·0			21	31·6
		21	58·7		18	1	9·2		6	4	18·7		22	7	27·2
	2	7	54·4			11	4·9			14	14·3			17	22·8
		17	50·1			21	0·5		7	0	9·9		23	3	18·4
	3	3	45·8		19	6	56·1			10	5·6			13	14·0
		13	41·4			16	51·8			20	1·2			23	9·6

System II.

	G.M.T.				G.M.T.				G.M.T.				G.M.T.		
1899.	d	h	m	1899.	d	h	m	1899.	d	h	m	1899.	d	h	m
Mar.	24	9	5·2	Apr.	9	12	13·1	Apr.	25	15	20·9	May	11	18	29·4
		19	0·8			22	8·7		26	1	16·5		12	4	25·0
	25	4	56·4		10	8	4·3			11	12·1			14	20·6
		14	52·0			17	59·9			21	7·6		13	0	16·3
	26	0	47·6		11	3	55·4		27	7	3·2			10	11·9
		10	43·2			13	51·0			16	58·8			20	7·5
		20	38·8			23	46·6		28	2	54·4		14	6	3·1
	27	6	34·4		12	9	42·2			12	50·0			15	58·7
		16	30·0			19	37·8			22	45·7		15	1	54·3
	28	2	25·6		13	5	33·4		29	8	41·3			11	49·9
		12	21·1			15	28·9			18	36·8			21	45·6
		22	16·7		14	1	24·5		30	4	32·4		16	7	41·2
	29	8	12·3			11	20·1			14	28·0			17	36·8
		18	7·9			21	15·6	May	1	0	23·6		17	3	32·5
	30	4	3·5		15	7	11·2			10	19·2			13	28·1
		13	59·1			17	6·8			20	14·8			23	23·7
		23	54·6		16	3	2·4		2	6	10·4		18	9	19·4
	31	9	50·2			12	57·9			16	6·0			19	15·0
		19	45·8			22	53·5		3	2	1·6		19	5	10·6
Apr.	1	5	41·4		17	8	49·1			11	57·2			15	6·2
		15	37·0			18	44·6			21	52·8		20	1	1·9
	2	1	33·5		18	4	40·2		4	7	48·4			10	57·5
		11	29·1			14	35·8			17	44·0			20	53·1
		21	24·7		19	0	31·4		5	3	39·7		21	6	48·8
	3	7	19·3			10	27·0			13	35·3			16	44·4
		17	14·9			20	22·6			23	30·9		22	2	40·0
	4	3	10·4		20	6	18·2		6	9	26·5			12	35·7
		13	6·0			16	13·9			19	22·1			22	31·3
		23	1·6		21	2	9·5		7	5	17·7		23	8	26·9
	5	8	57·2			12	5·1			15	13·3			18	22·6
		18	52·8			22	0·6		8	1	8·9		24	4	18·3
	6	4	48·4		22	7	56·2			11	4·5			14	13·9
		14	44·0			17	51·8			21	0·1		25	0	9·6
	7	0	39·6		23	3	47·4		9	6	55·7			10	5·2
		10	35·2			13	43·0			16	51·3			20	0·9
		20	30·8			23	38·6		10	2	46·9		26	5	56·5
	8	6	26·4		24	9	34·2			12	42·5			15	52·2
		16	22·0			19	29·8			22	38·1		27	1	47·8
	9	2	17·6		25	5	25·4		11	8	33·7			11	43·5

System II.

G.M.T. 1899. d	h	m	G.M.T. 1899. d	h	m	G.M.T. 1899. d	h	m	G.M.T. 1899. d	h	m
May 27	21	39·1	June 13	0	50·5	June 29	4	3·5	July 15	7	17·7
28	7	34·8		10	46·2		13	59·2		17	13·5
	17	30·4		20	41·8		23	55·0	16	3	9·2
29	3	26·1	14	6	37·5	30	9	50·7		13	5·0
	13	21·7		16	33·2		19	46·4		23	0·7
	23	17·4	15	2	28·9	July 1	5	42·1	17	8	56·5
30	9	13·0		12	24·6		15	37·8		18	52·2
	19	8·7		22	20·4	2	1	33·5	18	4	48·0
31	5	4·3	16	8	16·1		11	29·3		14	43·8
	15	0·0		18	11·8		21	25·0	19	0	39·6
June 1	0	55·7	17	4	7·5	3	7	20·8		10	35·4
	10	51·3		14	3·2		17	16·6		20	31·1
	20	47·0		23	58·9	4	3	12·3	20	6	26·9
2	6	42·7	18	9	54·6		13	8·0		16	22·7
	16	38·3		19	50·3		23	3·8	21	2	18·5
3	2	34·0	19	5	46·0	5	8	59·5		12	14·3
	12	29·7		15	41·7		18	55·3		22	10·0
	22	25·4	20	1	37·4	6	4	51·0	22	8	5·8
4	8	21·1		11	33·2		14	46·7		18	1·6
	18	16·8		21	28·9	7	0	42·5	23	3	57·4
5	4	12·4	21	7	24·6		10	38·2		13	53·2
	14	8·1		17	20·3		20	34·0		23	49·0
6	0	3·8	22	3	16·0	8	6	29·7	24	9	44·8
	9	59·5		13	11·7		16	25·4		19	40·5
	19	55·1		23	7·4	9	2	21·2	25	5	36·3
7	5	50·8	23	9	3·2		12	17·0		15	32·1
	15	46·5		18	58·9		22	12·7	26	1	27·8
8	1	42·2	24	4	54·6	10	8	8·5		11	23·6
	11	37·9		14	50·3		18	4·2		21	19·4
	21	33·6	25	0	46·1	11	4	0·0	27	7	15·2
9	7	29·3		10	41·8		13	55·7		17	11·0
	17	24·9		20	37·5		23	51·5	28	3	6·8
10	3	20·6	26	6	33·2	12	9	47·3		13	2·6
	13	16·3		16	29·0		19	43·1		22	58·4
	23	12·0	27	2	24·7	13	5	38·8	29	8	54·1
11	9	7·7		12	20·5		15	34·6		18	49·9
	19	3·5		22	16·2	14	1	30·4	30	4	45·7
12	4	59·2	28	8	12·0		11	26·2		14	41·5
	14	54·8		18	7·7		21	21·9	31	0	37·3

System II.

1899.	d	h	m	1899.	d	h	m	1899.	d	h	m	1899.	d	h	m
July	31	10	33·1	Aug.	12	20	27·2	Aug.	25	6	21·7	Sept.	6	16	16·6
		20	28·9		13	6	23·0			16	17·6		7	2	12·4
Aug.	1	6	24·7			16	18·8		26	2	13·4			12	8·2
		16	20·5		14	2	14·7			12	9·2			22	4·1
	2	2	16·3			12	10·5			22	5·1		8	7	59·9
		12	12·2			22	6·3		27	8	0·9			17	55·7
		22	8·0		15	8	2·1			17	56·7		9	3	51·6
	3	8	3·8			17	57·9		28	3	52·6			13	47·4
		17	59·6		16	3	53·7			13	48·4			23	43·3
	4	3	55·4			13	49·6			23	44·2		10	9	39·1
		13	51·1			23	45·4		29	9	40·1			19	34·9
		23	46·9		17	9	41·2			19	35·9		11	5	30·7
	5	9	42·7			19	37·0		30	5	31·7			15	26·5
		19	38·5		18	5	32·8			15	27·5		12	1	22·3
	6	5	34·3			15	28·6		31	1	23·3			11	18·2
		15	30·1		19	1	24·4			11	19·1			21	14·1
	7	1	25·9			11	20·2			21	14·9		13	7	9·9
		11	21·7			21	16·1	Sept.	1	7	10·8			17	5·8
		21	17·5		20	7	11·9			17	6·6		14	3	1·7
	8	7	13·3			17	7·7		2	3	2·5			12	57·5
		17	9·1		21	3	3·5			12	58·3			22	53·3
	9	3	4·9			12	59·4			22	54·1		15	8	49·0
		13	0·7			22	55·2		3	8	49·9			18	44·8
		22	56·6		22	8	51·0			18	45·7		16	4	40·6
	10	8	52·4			18	46·8		4	4	41·5			14	36·5
		18	48·2		23	4	42·7			14	37·4		17	0	32·3
	11	4	44·0			14	38·5		5	0	33·2			10	28·2
		14	39·8		24	0	34·3			10	29·1			20	24·0
	12	0	35·6			10	30·1			20	24·9		18	6	19·9
		10	31·4			20	25·9		6	6	20·8				

A list of the times of elongation of the fifth satellite is given in the *Connaissance des Temps*, 1899, pp. 616, 617. It may be mentioned here that the *Connaissance des Temps* for 1899 and following years gives ephemerides for the satellites of *Mars*, *Saturn*, *Uranus*, and *Neptune* in the same form as those formerly contributed to the *Monthly Notices* by Mr. Marth.

Benvenue, Ulundi Road, Blackheath, S.E.
1898 *November* 11

Mr. Denning has just sent me an observation, from which it appears that the great red spot followed the zero meridian of System II. by $52^{m}\cdot7$, on November 29

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIX. DECEMBER 9, 1898. No. 2

Sir R. S. BALL, LL.D., F.R.S., PRESIDENT, in the Chair.

Lieut. Tristan Dannreuther, R.N., F.R.G.S., H.M.S. *Leander*, Pacific Station, Esquimault, British Columbia; and

Charles Thomas Whitmell, M.A., B.Sc., Invermay, Headingley, Leeds,

were balloted for and duly elected Fellows of the Society.

O. Backlund, Director of the Observatory, Pulkova, Russia;

Edward Emerson Barnard, D.Sc., F.R.A.S., Yerkes Observatory, Williams Bay, Wisconsin, U.S.A.;

Sherburne Wesley Burnham, M.A., F.R.A.S., Government Building, Chicago, U.S.A.;

Commandant G. Defforges, Service Géographique de l'Armée, Paris;

James Edward Keeler, D.Sc., F.R.A.S., Director of the Lick Observatory, California, U.S.A.;

Henry A. Rowland, Johns Hopkins University, Baltimore, Md., U.S.A.; and

Prof. Wilhelm Schur, Director of the Observatory, Göttingen, Germany,

were balloted for and duly elected Associates of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

E. M. Antoniadi, Astronome, Observatoire de Juvisy, Seine-et-Oise, France (proposed by Capt. W. Noble);

John Jepson Atkinson, Barrister-at-Law, Cosgrove Priory, Stony Stratford (proposed by A. A. Common);

W. Lee Dickinson, M.D., F.R.C.P., Assistant Physician, St. George's Hospital, 9 Chesterfield Street, Mayfair, W. (proposed by E. J. Spitta);

John James Hall, L. and S.W. Railway, London; and Observatory Cottage, Datchet Road, Slough, Bucks (proposed by W. H. Walmsley);

Joseph Larmor, M.A., D.Sc., F.R.S., St. John's College, Cambridge (proposed by H. F. Newall);

John H. Reynolds, Malvern House, Trinity Road, Birchfield, Birmingham (proposed by Sir J. B. Stone);

Charles Almeric Rumsey, B.A. (Trinity College, Cambridge), Master at Dulwich College, London, S.E. (proposed by E. T. Whittaker);

Charles Stevens, Civil Servant, 10 Wemyss Road, Blackheath, S.E. (proposed by P. L. H. Davis);

William Harold Tingey, B.A., F.R. Met. Soc., Rede Court, Rochester, Kent (proposed by H. J. Adams);

Thomas Weir, Secretary, North Western (Manchester) Branch of the British Astronomical Association, 56 Parkfield Street, Moss Lane East, Manchester (proposed by E. W. Maunder); and

Algernon Charles Legge Wilkinson, B.A., Trinity College, Cambridge (proposed by E. T. Whittaker).

Sixty presents were announced as having been received since the last meeting, including amongst others :—

Ch. André, Traité d'astronomie stellaire, 1re partie, presented by the Author; Bonn Beobachtungen, Band vii., Fortsetzung und Schluss (Argelander, Nachgelassene Beobachtungen, &c.), presented by the Observatory; H. Coddington, Optics, second edition, and W. Kitchener, The Economy of the Eyes, part 1, presented by Prof. Meldola; Galileo, Opere, edizione nazionale, vol. viii., presented by the Italian Government; Lowell Observatory, Annals, vol. i., presented by Percival Lowell; Leiden Observatory, Annalen, Band 7, presented by the Observatory; Madras Observatory Report for 1897–98, and on the Eclipse Expedition of 1898 January, presented by the Observatory; Milan, R. Inst. Lombardo, Memorie, vol. xviii. fasc. 5 (G. V. Schiaparelli, Origine del sistema planetario eliocentrico presso i Greci), presented by the Institute; Companion to the Observa-

tory, 1899, presented by the Editors; *American Nautical Almanac* papers, vol. vi., part 4 (Newcomb, Tables of *Mars*), presented by the *American Nautical Almanac* Office; and a series of solar photographs (original negatives), presented by G. J. Newbegin.

The Division Errors of the Greenwich Transit Circle and some questions related to Them. By F. W. Dyson and W. G. Thackeray.

[*Abstract.*]

In this paper an account is given of a new determination of the division errors of the Greenwich Transit Circle, made in 1898, with a view to explaining the discordances in the circumpolar observations as given by the Astronomer Royal in his report to the Board of Visitors in 1898 June. As the Greenwich Transit Circle is ordinarily read by six equidistant microscopes, the determination of the division errors consists in the subdivision of an arc of 60°. This is first divided into three parts, and the arcs of 20° subdivided into the arcs of 5°, and then the 5° arcs subdivided into single degrees. The first determination was made in 1851, taking 0°, 20°, 40° as the primary divisions. This was repeated in 1856. In 1871 a new determination was made, taking 10°, 30°, 50° as the primary divisions. In 1898 two determinations were made, taking 5°, 25°, 45°, and 15°, 35°, 55° as the primary divisions. The final result of the errors of the 5° divisions was obtained from the mean of the determinations in 1856, 1871, and the two determinations in 1898. A further determination of the single degree divisions was made, and of the 5′ divisions used in the observations of the close polar stars. Tables are given of the new division errors, and of corrections to those in use in the different years since 1851.

The corrections thus determined to the division errors in use are applied to—

(1) The residuals in the R—D discordance.
(2) The differences between the N.P.D.'s obtained from observations made above and below pole at Greenwich given in the Introduction to the 1880 Catalogue.
(3) The differences between the Greenwich and Cape N.P.D.'s, as given in the Introduction to the Cape 1885 Catalogue.
(4) The Greenwich Sun observations.

The following table, derived from the Introduction to the Greenwich Catalogue for 1880 by grouping the stars in zones of 3°, gives the excess of the N.P.D. from observations made above pole:—

Mean N.P.D. of Group.	Excess of N.P.D. above Pole. Old Division Errors.	New Division Errors.	Weight.
°	″	″	
2·3	−0·47	−0·22	20
5·4	− ·16	− ·15	21
8·5	− ·02	− ·02	36
10·9	− ·18	− ·12	29
13·8	+ ·25	+ ·16	47
17·0	+ ·17	− ·07	40
19·7	+ ·19	− ·05	54
22·6	+ ·19	+ ·10	64
25·3	− ·05	+ ·05	68
28·4	− ·22	− ·02	78
31·5	− ·66	− ·46	37
34·5	− ·25	− ·15	25
38·4	− ·44	− ·59	21

It will be seen that the well-known discordance of the close polars from those at about 20° N.P.D., though not entirely removed, is largely diminished.

The discussion of the Greenwich and Cape observations given in the Introduction to the Cape Catalogue for 1885 was repeated in part, and a very satisfactory reduction of the discordances resulted. Dr. Gill found that whereas the probable error of an observation is about $\pm 0''\cdot 50$, yet the residuals of his equations (when solved on different suppositions as to the refraction and R−D discordance) corresponded to probable errors of $\pm 1''\cdot 57$, $\pm 1''\cdot 49$, $\pm 1''\cdot 60$, $\pm 1''\cdot 46$. The new division errors reduce these quantities to $\pm 0''\cdot 90$, $\pm 0''\cdot 75$, $\pm 1''\cdot 10$, $\pm 0''\cdot 73$. In view of the large reduction in these quantities, especially the 2nd and 4th, where the Cape observations are corrected for R−D discordances, it would appear that division error, and not irregular heating of the observing room, is the cause.

The question of refraction and R−D is briefly discussed in a similar way to that given in the Cape Catalogue for 1885, using the figures given by Dr. Gill, but correcting them for division error and for an important numerical error which was made early in the discussion. It appears from this that no definite conclusion can be drawn as to the correctness of applying an R−D discordance to the Cape observations.

Corrections to the division errors are also applied to the results of the Greenwich Sun observations.

The refraction most suitable to the Greenwich observations is discussed briefly. The conclusions arrived at on this oft-discussed topic are :—

(1) That the refractions of the Tabulæ Regiomontanæ satisfy

the Greenwich circumpolar observations down to 75° Z.D., as well as those of the Pulkova Tables

(2) That accordance between the Cape and Greenwich N.P.D.'s would be secured by the Pulkova Tables.

(3) The Greenwich Sun observations require the refractions of the Tabulæ Regiomontanæ.

Note on Pogson's Manuscripts, relating to his proposed "Atlas of Variable Stars." By J. G. Hagen, S.J.

(*Communicated by the Secretaries.*)

During the astronomical congress held this summer (1898) at the Harvard College Observatory, the writer was kindly permitted to examine the manuscripts of the late N. R. Pogson, which are preserved in a fireproof building of that observatory.* The readers of the *Notices* are aware, at least in a general way, of Pogson's plans from a report in vol. xx. p. 143, and of the unfinished state of his work from the Obituary in vol. lii. p. 235. The following note is intended to give in outline the character and progress of his work as far as they are shown by the manuscript itself. From the Obituary we only recall that Pogson carried on his work in three different places—namely, at the Radcliffe Observatory from 1851 to 1858, at the Hartwell Observatory from 1859 to 1860, and in Madras from 1861 to 1891, the year of his death.

The best knowledge of Pogson's work on his proposed Atlas would of course be obtained from the publication of the list of all the finished catalogues and charts. Yet as this list is rather extensive, it seems better to give here only a summary statement.

The manuscripts consist of catalogues of star places and magnitudes, and of a few charts plotted by hand. There is no introduction to give information on the plan of the Atlas, the methods employed or the instruments used, yet the catalogues and charts, with a few interspersed notes, will give a pretty complete idea of Pogson's work.

* Inquiry was made of Father Hagen by the Secretaries, how the papers of Mr. Pogson came to be at Harvard College Observatory. In reply, Father Hagen kindly sent a letter from Professor Pickering, giving the following information:—

"The papers were sent to the Harvard College Observatory after correspondence with the family of Mr. Pogson, and especially with his sister, Mrs. Baxendell. I understood that her son expected to reduce Pogson's observations of variable stars, and I recommended that these maps and catalogues should be published in connection with them. I shall of course be glad to take any steps which will secure their publication. Meanwhile, like other extensive collections of observations deposited here, they are available for any use that can be made of them."

1. The *general plan* of the work comprised all the telescopic variables in the northern and southern hemispheres, also a great number of suspected variables, and finally the temporary stars. There is no reference to the naked-eye variables. For each variable a separate chart with catalogue was contemplated, except when two or three variables are sufficiently close to each other. Each chart was to measure 1° 20′ in declination, and a corresponding amount in right ascension, and was to comprise all the stars of this area down to the 13th magnitude. On a very few catalogue sheets the magnitudes go as far as the 14th, while in some they reach only $12\frac{1}{2}^{M}$, according to the progress of the "interpolations," which will be mentioned below. The original plan seems to have fixed the limit of magnitudes to 12^{M}, for in a note to *S Virginis*, in 1862, Pogson says: "Many minute stars have of late been observed much too faint for insertion in any map as 12 mag."

2. About the *instrumental equipment* and *methods of observation* we learn from the manuscripts that equatorials were used with magnifying powers of 84 (from 1859 December), 52 (in 1860), and 70 (from 1865 April), and a field of view of over half a degree. Several "reticles" are mentioned: "a new reticle adapted for general use" in 1859 (note to *o Ceti*), a "Smythian telescope reticle applied to the equatorial by Lerebours and Secretan" in 1865 (note to *R Aurigæ*), and finally a "new reticle made by Messrs. P. Cir (?) & Sens, Madras," in 1875 (note to *U Cephei*, p. 2). Of what material or in what shape these reticles were made is not recorded. However from a slip referring to the catalogue of *T Cassiopeiæ* (commenced in 1874) it is possible to compute the scale value of the reticle then used. From several "interpolated" stars follows: one division=2′·5.

The observations were arranged by Pogson in such a way that he first "noted the magnitudes and declinations," and then several days or weeks later "put in the right ascensions" (notes to *S Virginis* and *R Herculis*, 1862–63).

His estimates of brightness were not made by intervals or steps, but directly to full magnitudes, without decimals. Half magnitudes are found near the limit of visibility, like 12.13 or 13.14.

The declinations were estimated by tenths of a scale division. Hence for the scale value 2′·5 they may have reached an exactness of a quarter of a minute.

The right ascensions were determined in stripes which had generally a width of 20′ in declination, but sometimes of 30′ or of 10′, according to the density of the field of view. Whether the eye-and-ear method was used, or a registering apparatus, is not said. After these stripes or zones were finished, fainter stars were inserted by "interpolation," usually several years later. Some star, bright or faint, was taken as zero point, and others connected with it by notes like the following: 12, 2·5 sf. 5, or 12.13, 1 nf. 25, which, from a comparison with the catalogue,

must be interpreted as follows: 12^{M}, $-6'\cdot2+5^{s}$ and 12.13^{M} $+2'\cdot5+25^{s}$ respectively.

3. The *catalogue* for each variable star consists of four parts: First, an extract of fundamental stars from meridian observations (Argelander, Bessel, Brisbane, Cape, Cordoba, Lacaille, Lalande, Madras, Radcliffe), to which are added comparison stars determined by Chacornac, Winnecke, or Schönfeld. Secondly, a fundamental list of stars made from these extracts and reduced to 1860·0. Reductions to 1900·0 are prepared on separate sheets, but were not carried out. The third part of the catalogue gives the magnitudes and star-places in four distinct zones, each 20′ wide. The magnitudes are given without decimals, as was mentioned before. The positions are not given differentially from the variable, but absolutely for the equinox of 1860·0, to full seconds of time and tenths of minutes of arc. The fourth part of the catalogue contains the faintest stars determined by interpolation.

There are about 75 stars on a full page of the catalogue, and about 50 stars on an average page (including fractions of pages). The average number of pages for a variable is 4½, from which follows that the average number of stars for a chart is over 200.

The number of catalogues which seem to be complete is this:

84 variables with faint minima ($<10^{M}$),
22 „ „ bright „ ($\geqq10^{M}$),
21 suspected variables (never confirmed),
7 temporary stars, or

134 in all. In these catalogues there is no difference as to the limit of magnitude, whether the variable have a faint or a bright minimum, all being carried down to 13^{M}.

Of the unconfirmed variables 10 seem to have been suspected by Pogson himself, since they are not found in any catalogue of variable stars; 5 of them occur in Schönfeld's Catalogues I. or II., but are marked as doubtful; and the remainder are mentioned by Gore or Gould as suspected of variability. The catalogues of these objects are as elaborate as the others, the number of stars contained being on the average over 200, and the limit of magnitude 13^{M}.

Of the temporary stars 3 are ancient (of 1572, 1600, and 1604), the other 4 were contemporary with Pogson, that of 1863 having been seen by himself only.

4. The *charts*, of which there are 18, are not Pogson's working charts, but seem to be intended either as specimens for the engraver or as the final copies for reproduction. They are about 4 inches square, with the name of the variable written above, the range and period of variation below, and the position for setting on the right and left. The projection of the net is conical, and the coordinates are drawn from 10′ to 10′ in declination, and from 1^{m} to 1^{m} in right ascension. As the central cross

of these coordinates is thus marked by a multiple of 10′ and 1^{m}, the variable falls a little outside of the centre of the chart.

The inspection of the manuscripts, and even the reading of this summary statement, cannot fail to produce the highest admiration for Mr. Pogson's activity and perseverance, and this admiration is greatly increased if we recall his extended meridian work and other official duties. The latter may have been the occasion that his greatest activity on the Atlas fell in the years 1863–65, with 39 catalogues, and in 1874–78, with 35 catalogues. He commenced his first catalogue in 1853, at the age of 24, and his last in 1882, or 9 years before his death. To keep up an arduous work like this for thirty years, without seeing it in print, and even without a definite prospect of ever finishing it, supposes an enthusiasm that is indeed very rare.

Two questions naturally offer themselves to us: why was such enthusiasm and labour not crowned with more success, and what should be done with the manuscripts?

While there may be several answers to the former question, one is given by the manuscript itself: the plan was too vast for any one man, considering the area of the charts and their number. Had Pogson limited at least the one or the other he would have been able to accomplish his plan, and the Atlas would have been none the less valuable. Indeed, an area as small as 30′ square seems almost unnecessarily large for the insertion of the smallest comparison stars, and this would have been less than one-seventh of the area that Pogson undertook to fill out. The number of the charts might have been limited by setting aside the variables with bright minima, the suspected variables and the temporary stars. As regards the first class, one may wonder what the purpose could have been of mapping the stars down to the thirteenth magnitude, when the minimum brightness of the variable never falls below the tenth. Some examples will illustrate this question. The catalogue for *T Monocerotis* (variation 6^{M}–8^{M}) has nine pages with nearly 500 stars; that for *S Puppis* (7^{M}–9^{M}) eight pages; that for *U Sagittarii* (7^{M}–8^{M}) seven pages; that for *μ Cephei* (4^{M}–5^{M}) eight pages; and that for *η Argûs* (Carinæ), which varies from 1^{M} to 7^{M}, no less than fifteen pages, with 845 stars. And in all these cases the catalogues give the magnitudes down to the thirteenth.

Pogson's work on suspected variables was crowned with many discoveries (in Chandler's Catalogue I. no less than fourteen variables are connected with his name); yet elaborate charts for objects, whose variability was confessedly doubtful, were a great loss of time for him, and would have been an unnecessary expense to the subscribers of the Atlas.

Finally the temporary stars are not variable stars in the proper sense of the term as now used, and do not belong to a catalogue or atlas of variable stars. Interspersed among the variables properly so called they are apt to lead observers to waste their time on them.

The other question: what should be done with the manuscripts remains an open problem. The plotted *charts* are not accurate enough for photographic reproduction, nor will they ever be used for engraving, since charts can be engraved directly from the catalogues with greater accuracy. The *catalogues*, on the other hand, could be published at less expense, and would afford a welcome comparison with other work of the same kind, or with the ecliptic charts of Chacornac, Peters, and Palisa.

Since the readers of this note are probably aware of the forthcoming *Atlas Stellarum Variabilium*, it may be of interest to them to know that its plan was laid out previous to any knowledge of Pogson's work, and that its observations were practically finished before his manuscripts were examined. It seemed to be preferable to make no use of Pogson's catalogues in preparing this Atlas and to leave a comparison of the two works to a future time when his results will be more generally accessible.

Georgetown College Observatory:
1898 *October* 10.

On a New Instrument for measuring Astrophotographic Plates. By David Gill, C.B., F.R.S., &c., Her Majesty's Astronomer at the Cape of Good Hope.

Introductory.

The apparatus formerly employed at the Cape for measuring "Catalogue plates" resembled in general construction the one originally made by Messrs. Repsold of Hamburg for Professor Bakhuyzen, and which is described by him (*Bulletin du Comité Permanent*, tome i. pp. 169–173).

In lieu of the original microscope by which a single coordinate of the image of a star on the plate could be projected on and measured by a scale divided on metal, Messrs. Repsold made for me a very perfect micrometer having two screws at right angles to each other, by which both coordinates of a star could be measured relative to the sides of the including réseau.

With this apparatus the coordinates of about 8,000 stars were measured. The method of observation was to point on one réseau-line, then on the edges of the star-disc, then twice on the centre of the star-disc, then on the opposite réseau-line, and finally to repeat the operation in the reverse order.

Thus the measurement of each coordinate, and of the star's diameter, involved sixteen pointings and sixteen readings of the microscope. The process was unquestionably very accurate, but it cost far too much time in observing and in reduction to offer any hope of completing the programme of observation in a reasonable time—at least with the means placed at my disposal.

Having examined Professor Turner's now well-known method, by which the coordinates of the star's image are referred to glass scales placed in the common focus of the eyepiece and object-glass of the microscope, I could not satisfy myself that results of adequate accuracy could be secured by such means. Trial of the apparatus convinced me that the observer could not be at all certain of estimating the tenth part of the 3″ intervals into which the scales are ruled, especially as division on glass with a diamond does not yield very clean and sharp fine lines; and, even supposing that the observer could exactly estimate the $\frac{1}{10}$th part of such 3″ intervals, his smallest estimated measure is 0″·3, which is extravagantly large, seeing that, on a fairly good plate, a star's image can be pointed upon with a filar micrometer with a probable error rather under than over ±0″·1. Indeed, with such a method of observation the calculation of true probable error is impossible, because, unless the definition of the microscope is very bad, or the image of the star is bad, or the scales are defective in precision of division, the observer should always observe to the same $\frac{1}{10}$th of a division. This criticism does not apply quite strictly to Professor Turner's last computations of the probable error of the Oxford measures, where the plate is reversed 180° without reversing the micrometer scale, because in this case the réseau-lines intersect the scales at different points from those of the previous measurement. But no confidence can be placed in estimates of probable error by this method of observation when, as at Greenwich, the scales are reversed with the plate, and the réseau-lines are referred to the same points of the scales in the two positions of the plate.

Recognising the necessity for more rapid means of working, I endeavoured to devise an instrument which, retaining the rapidity of Professor Turner's method, should also retain the accuracy which is attainable with the filar micrometer. The result has fully realised my expectations, thanks to the artistic skill and care of Messrs. Repsold, to whom I entrusted the carrying out of my plans.

The Essential Features of the New Instrument.

The essential conditions of construction are:—

1. The micrometer to be webbed with a "fixed square," 5 mm. × 5 mm., the sides of this square being parallel spider-webs 4″ (of arc) apart. The size of the square is reckoned from centre to centre of these double webs.
2. The object-glass of this micrometer to be placed midway between the plane of the photographic plate and the plane of the webs.
3. The two micrometer screws at right angles to each other which actuate the movable slides to have heads divided into 100 parts, one revolution = 0·5 mm.; so that ten revolutions are = 5 mm., or = the interval between two

adjacent réseau-lines, or=the interval between the sides of the fixed square of webs.

4. Two other screws, the heads of which are not graduated, to give motions to the whole micrometer-box through ± 1 mm. in directions parallel to the axes of the two micrometer screws.
5. Each micrometer screw to move a system of six parallel wires placed $4''$ (of arc) apart from each other. These wires to serve, not only for pointing on stars to determine their coordinates (in manner afterwards described), but also for estimating their diameters in terms of these $4''$ intervals.
6. All the essential parts of the micrometer, including the slides, micrometer-box, tube, &c., to be of steel or cast iron, so that changes of temperature shall not affect the adjustments.

The necessary adjustments are the following :—

a. The webs of each set of movable wires shall, *inter se*, be strictly parallel, and the two sets shall be strictly at right angles to each other.

b. The double webs composing the sides of the fixed square shall be strictly parallel, and shall form a true square of exactly ten revolutions of the screw on the side.

c. The two micrometer screws shall be without sensible periodic or other error, and exactly alike in pitch.

d. The image of a normal réseau-square, as viewed in the microscope, shall exactly coincide with the square formed by the fixed webs ; that is to say, the image of the sides of a normal réseau-square shall measure exactly 10 screw revolutions.

e. The micrometer readings for coincidence of the movable webs with the webs of the fixed square shall be exactly $0^{R}\cdot000$ and $10^{R}\cdot000$.

Assuming for the moment that these conditions are rigidly realised, we have the following very simple *modus operandi* :—

a. By means of the quick rack-motion move the plate so as to bring the réseau-square into the centre of the field of the micrometer ; then, by means of the micrometer screws with undivided heads, perfect the coincidence of the fixed wires with the image of the réseau-square, as in the figure on page 64.

β. By means of one of the micrometer screws, X, point the movable set of six wires on the image of the star-disc.

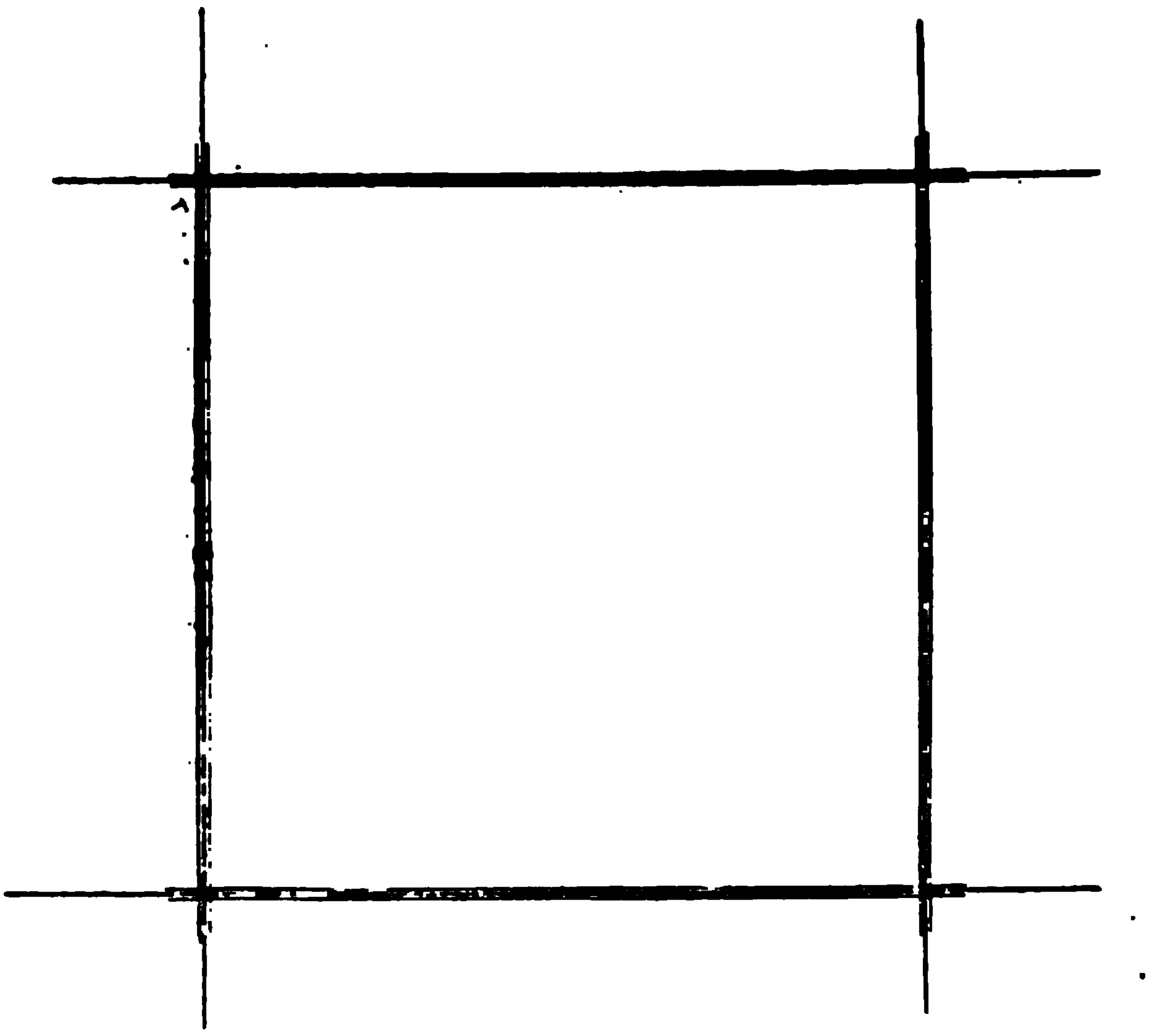
γ. Similarly bisect the star-image with the screw Y.

δ. Estimate the diameter of the image in terms of the $4''$ intervals of the movable webs.

The reading of the pointing *β* is then the required coordinate in x, and that of γ the required coordinate in y ; or, if the plate

is reversed 180°, the readings have to be subtracted from $10^{\text{R}}\cdot000$.

The whole process is so simple that an observer without any previous knowledge or experience in practical work of the kind can, after very short training, easily measure the two coordinates of eighty stars per hour (including diameters); and, were it not that the observers are instructed to work very carefully, a larger number could be measured in the same time.



Coincidence of fixed wires with image of réseau-square.

It remains to be described how the necessary adjustments are made, how preserved constant, what effect possible residual errors in these adjustments may have in the resulting coordinates, and what accuracy experience has shown can be attained in the resulting coordinates.

Adjustment *a*.—The six parallel webs, 4″ apart, which are moved by each of the measuring screws, have no adjustment for parallelism with each other, but the web-furrows have been ruled with an exquisitely fine and sharp cutter in a ruling machine of such perfection that no error in their parallelism can be detected even when the webs are successively placed in all but apparent contact with one of the fixed webs under an eyepiece of $\frac{1}{6}$-inch focal length, specially used for this purpose and for determining coincidence.

For adjustment of the two sets of six webs at right angles to each other, the ruling of the web-furrows at one side of one of the movable frames has been made, not on the upper surface of the frame itself, but on a small supplementary slide attached to

the main frame. This supplementary slide is adjustable by two fine opposing screws, the heads of which can be turned by a long screw-driver of small diameter, which may be inserted through suitable holes in the sides of the micrometer box. When the adjustment is completed these holes are closed by small metal plugs to exclude dust. The adjustment can be made by placing an original réseau, the lines on which are known to be perfectly at right angles to each other, under the micrometer, and making the two sets of movable webs to coincide with the image of the réseau-lines. No trace of change in the accuracy of this adjustment can be detected.

Adjustment *b.*—The parallelism to each other of the double webs, 4″ apart, which constitute the four sides of the fixed square has been secured once for all by the perfection of the ruling of the web-furrows. It remains—

(1) To adjust two sides of the square parallel to their corresponding movable webs.
(2) To adjust the two opposite sides, not only also parallel to the movable webs, but also exactly 10·000 revolutions of the screw distant from the other two sides.

For this purpose the web-furrows at one extremity of one of the sides of the square are ruled, not on the central fixed frame itself, but on a small supplementary plate, which has slight adjustment by means of a screw and opposing spring. The web-furrows on the opposite sides of the fixed frame are ruled, not in the frame, but on two plates provided with similar adjustments. Access to the heads of these screws is attained in the same way as in adjustment *a.* With a little care and patience it is thus comparatively easy to make the sides of the square strictly parallel to the movable webs, and each side of the square to measure exactly 10·000 revolutions—at least within $0^{\mathrm{R}}.001$ or $0^{\mathrm{R}}.002$.

Adjustment *c.*—This demands perfect equality and perfection in truth of the two screws, and is necessarily left to the artist. Messrs. Repsold have apparently attained practical perfection by careful final grinding of both screws in the same matrix. The screws are practically identical, and can even be interchanged in the micrometer without affecting the apparent measured lengths of the sides of the fixed square.

Adjustment *d.*—The microscope is provided with two focussing adjustments, both of which are regulated by screws with divided heads acting against opposing springs.

(1) moves the object glass (which is mounted on an inner tube sliding in the outer tube), nearer to or farther from the plate.
(2) moves the micrometer box nearer to or farther from the object glass—in other words, changes the total length of the fixed tube.

By means of these two screws it is very easy to adjust the micrometer so that the images of the sides of réseau-square fit symmetrically between the parallel webs of the fixed square. This adjustment once made is not liable to change, but on account of shrinkage of the film and division error of the réseau, it is never found that all the images of the réseau-squares of any plate exactly fit the fixed square.

The fact that the object glass is placed midway between the conjugate foci offers the great advantage that, by a small movement of the object-glass, the size of the image of the réseau-square can be changed relative to the size of the "fixed square" of the micrometer without disturbing the sharpness of the images. Thus, for the measurement of each separate coordinate it becomes possible to adjust the image of the including sides of the réseau-square to exact coincidence with the corresponding sides of the fixed square by simple movement of the screw (1).

As a matter of experience, however, the following plan is found to be more satisfactory, viz. to measure a number of squares on the plate, find the mean value, and, if that is not perfectly $=10^{R}\cdot000$, apply the necessary correction to the run by moving the graduated head of screw (1) through the required amount. When the image of any particular square (on account of division error in the original réseau or of shrinkage of the film) does not exactly fit the fixed square, then make a symmetrical pointing.

In this way we automatically make the reading $5^{R}\cdot000$ to correspond with the true middle point between the sides of the réseau-square, and practically we measure the distance of the star from this middle point in terms of true mean revolutions.

Adjustment *e*.—The rounded end of each micrometer screw is pressed against the flat end of an adjusting screw (which is tapped into the side of the micrometer box) by the counter spring of the micrometer slide. It is obvious that, by this screw, it is very easy to adjust the reading of the screw-head to zero for coincidence readings of the movable with the fixed wires.

Results of Experience with the New Instrument.

It may appear to the reader that a micrometer of this kind is a complex instrument liable to derangement in its adjustments either by unskilful handling or by change of temperature.

It is true that the design of the interior of the micrometer box is of necessity somewhat complex; but experience has shown remarkable constancy in the adjustments and extreme ease and simplicity in working. This result is due to the solidity and perfection of the design and workmanship, and to the similarity of the temperature coefficients of expansion of all the principal parts. As a matter of fact, since I made the final adjustments, I have only once had occasion to change them, and that was when one of the webs was accidentally broken and I had to dismount the micrometer to replace it.

Coincidence of the movable webs with the corresponding sides of the fixed square is determined for each screw at 0^R and 10^R, generally before the measurement of each plate; the results agree within $\pm 0^R{\cdot}002 = (\pm 0''{\cdot}06)$. But even if these errors were much larger they would have very little influence on the result of two pointings on reversed positions of the plate.

Every plate is measured twice—once in one position, once in a position reversed 180° with respect to the microscope. Two observers, sometimes three, take part in the measurement of each plate. One observer measures the coordinates of all the stars on the first 5′ zone, the other acting as clerk. The observers exchange work in the next 5′ zone, and so on till the plate is finished. When the plate is reversed each observer re-measures the same 5′ zones as he or she previously measured in the former position. Before any plate is measured the images of the reference stars on the plate (ten to twelve in number, the places of which have been specially observed on the meridian) are marked by circles in ink drawn on the reverse side of the plate, and these ten to twelve images are measured by all the observers who cooperate in the measurement of that plate.

The process above described has the following advantages :—

1. All personality depending on right and left directions of measurement, and hence on magnitude, is eliminated.
2. All index error, depending on the reading for coincidence of the movable with the fixed wires, is completely eliminated.
3. The outstanding error of run over ten revolutions is always very small, because, if after measuring a number of réseau-squares with the screw it is found that the mean is not exactly $10^R{\cdot}000$, the necessary correction is at once applied by moving the object glass nearer to or farther from the plate, the necessary amount of correction being known by the graduations on the head of the focussing screw. It would therefore be a very extreme error to adopt $\pm 0''{\cdot}1$ as the possible amount of outstanding error of run over ten revolutions.

If the fixed square is pointed symmetrically on the réseau-square, the reading "$5^R{\cdot}000 \pm$ index-error" must correspond to the true middle point between the réseau-lines (the sign of the index error being + in one position of the plate and − in the other position). Therefore, if a star is at or near $5^R{\cdot}0$, its coordinate will be determined free from error of run. If the star is situated near one side of the square, the coordinate would be affected by half the error of run over ten revolutions, *i.e.* in an extreme case by $\pm 0''{\cdot}05$. In all intermediate positions the effect of an error of run of $0''{\cdot}1$ in ten revolutions will lie between $0''{\cdot}00$ and $0''{\cdot}05$.

To derive an approximate idea of the accuracy of the method,

we may discuss the difference between the direct and reverse measures of coordinates actually obtained in practice.

This difference "direct *minus* reverse" arises from the following causes :—

(1) Accidental error of pointing the "fixed square" on the réseau-square.
(2) Accidental error of pointing the movable wires on the star's image.
(3) Twice the personal equation depending on magnitude, or on right and left directions of measurement.
(4) Twice the outstanding error of the zero adjustment for coincidence.
(5) A part (never greater than one-half) of the error of adjustment for run over ten revolutions.

Except near the corners of the plate, it very seldom happens that the difference between the readings direct and reverse amounts to $0^R{\cdot}02 = 0''{\cdot}6$. Whenever such a difference occurs (perhaps once in 50 or 100 stars) the readings in both positions of the plate are repeated.

At Greenwich and Oxford the rule seems to be to repeat the measures only when discordance "reverse minus direct" amounts to $1''{\cdot}5$!

To compute the probable error of observation, I have taken the plate No. 9722, zone $-41°$, $a_0 = 18^h\ 35^m$, in the measurement of which three observers took part, viz. Misses Bowman, Stephens, and Halkett.

The plate contains 702 measured stars, ten of which occur on the list of standard stars. The zones were equally divided amongst the three observers, each measuring her special zones in both reversed positions of the plate.

From the differences "direct minus reverse," without any corrections for constant differences, we find :—

	B	S	H
	R	R	R
"Direct – reverse" mean . . .	+0·0001	+0·0015	+0·0035
Mean of the squares of the differences "Direct – reverse"	0·000076	0·000081	0·000073
$\sqrt{\ }$ of the above (in arc) . . .	$\pm 0''{\cdot}261$	$\pm 0''{\cdot}270$	$\pm 0''{\cdot}255$

Whence we have

The probable error of 1 observation .	$\pm 0''{\cdot}123$	$\pm 0''{\cdot}127$	$\pm 0''{\cdot}121$
And the probable error of each coordinate resulting from the two observations in reversed positions of the plate	$\pm 0''{\cdot}088$	$\pm 0''{\cdot}090$	$\pm 0''{\cdot}085$

Of the original observations of the 702 stars eight had to be repeated for discordance between the readings in the two positions exceeding $\pm 0^R{\cdot}02$ $(= \pm 0''{\cdot}60)$.

These probable errors are perhaps slightly in excess of the true probable errors, because they include twice the coincidence error and perhaps a small error depending on run.

The better to determine how far this is the case, I give the results of the measures of the standard stars by each of the three observers.

Standard Star.	x			y		
	B	S	H	B	S	H
	R	R	R	R	R	R
(1)	8·795	8·802	8·803	7·636	7·637	7·644
(2)	9·248	9·240	9·245	0·040	0·033	0·036
(3)	8·043	8·050	8·043	5·182	5·178	5·178
(4)	2·266	2·264	2·262	0·231	0·225	0·220
(5)	9·040	9·039	9·040	4·336	4·337	4·329
(6)	2·536	2·528	2·534	1·628	1·626	1·625
(7)	0·697	0·692	0·690	3·617	3·618	3·618
(8)	8·212	8·216	8·205	8·698	8·703	8·707
(9)	2·256	2·260	2·266	5·140	5·134	5·138
(10)	5·616	5·604	5·615	4·815	4·820	4·813

If now we take the means for each coordinate of each star, and subtract these means from the corresponding coordinate obtained by each observer, and take the mean of the squares of the residuals thus formed, we get for the different observers :—

	B	S	H
Mean of the square of the residuals	0·0000115	0·0000092	0·0000134

These mean squares are = $\frac{2}{3}$ of the square of the mean error, because for each of the three residuals from each star there is one unknown quantity.

Thus :

	R	R	R
The mean error of a coordinate as derived by each observer is	±0·00415	±0·00371	±0·00448
And the corresponding probable errors in arc are	±0″·082	±0″·074	±0″·089

Description of Details of Construction.

The instrument, as shown in Plate 2, is built upon a circular cast-iron base-plate, which in use rests on a stand of walnut wood inclined at an angle of 45°.

The micrometer-holder is attached to a strong cast-iron tribrach, which is supported from the base-plate by three iron pillars.

Provision for motion of the plate in one direction is made by a strong cast-iron slide with two pairs of segmental bearings, which rest on the steel cylinder *a b* and on a single bearing on a

true plane formed on the base-plate. Motion at right angles to the former direction is given by a second slide, mounted similarly to the first slide upon the cylinder *c d*, and on a true plane *e* formed on the first slide.

To each cylinder is attached a bar of German silver, *f*, one side of which is toothed; the other side is graduated at each fifth millimetre. The handle A is connected with a pinion which works in the toothed side of the bar *f*, and gives quick motion to the plate in the direction of the axis of the cylinder *a b*. The smaller handle beside A clamps the slide to the cylinder *a b* when desired. The handle B similarly gives quick motion to the plate along the direction of the axis of the cylinder *c d*, and the smaller handle clamps the slide to the cylinder.

Each German silver scale has a double set of figures engraved upon it: one set, coloured black, corresponds with the réseau-readings in the "direct measures"; the other set, coloured red, corresponds with the réseau-readings in the "reverse measures."

Indices, which are adjustable to exact coincidence with the réseau-readings under the microscope, enable the observer to identify at sight the réseau-square under measurement. The two slides, being of considerable weight, are balanced by a counter-weight which is attached to a cord passing over the pulley C, so that the quick motion imparted to the slides by the handle A is equally easy in both directions.

The photographic plate is mounted on the upper slide, being pressed by springs, acting on its under surface, against three projecting stops which define the plane of the film. These stops and the planes of motion of the slide have been so carefully adjusted, once for all, that the film-surface of the plate is, and moves, perfectly at right angles to the axis of the microscope, and at a constant distance from its object-glass. The plate is also pressed by a spring, acting on the centre of its upper edge, against two stops, which can be moved by the screws *g* and *h*. These stops are simple projections on the ends of a strong spring which is fixed to the upper slide at *k*. The screws *g* and *h*, by bending this spring, permit the plate to be very easily adjusted, so that the réseau-lines are parallel to the axis of the cylinder *c d*. The projections at *g* and *h* touch the plate opposite the two extreme vertical réseau-lines. When the plate is moved to the extremity of its range on the cylinder *c d* (*i.e.* to the position shown in Plate 2), the extreme left-hand réseau-line is seen near the centre of the field of view of the microscope. To adjust the plate it is then only necessary to point a pair of the movable wires, or one side of the fixed square, on one of the horizontal réseau-lines near its left-hand extremity; then, by the handle B, move the plate to its full extent of range to the left: this brings the extreme right-hand réseau-line near to the centre of the micrometer field. If the same horizontal réseau-line still remains bisected, the adjustment is complete; if not, by means of the screw *h*, move the plate till the pointing is perfect; the adjust-

Monthly Notices of the Royal Astronomical Society. *Vol. LIX. Plate 2.*


6
13
4
8
7
15
3
16
10
9
14
5
1

ment is then perfected, so that the réseau-line remains bisected whilst the plate is traversed along the whole range of the cylinder *c d*.

The adjustment of the fixed square to parallelism with the réseau-lines is effected by two opposing screws, one of which is shown at *l*. By means of these screws the supporting tube of the micrometer may be delicately rotated in its bearing. This supporting tube, of cast iron, terminates in a broad flange and hollow pivot, and the latter fits smoothly in a hole in the tribrach.

The flange is held down by two screws with spring collars; the holes in the flange, by which these screws pass to the tribrach, being somewhat elongated, permit some rotation of the supporting tube of the microscope.

The screw *l* and its opposing screw pass through short arms (better seen on Plate 3), which are cast on the flange of the microscope-holder and press against a block on the tribrach. By these means the adjustment of the micrometer webs to parallelism with the réseau-lines can be made with the greatest certainty; and, once made, the adjustment of the orientation of the webs remains perfectly constant, although, of course, it is verified before the measurement of every plate.

For illumination of the field of the microscope Messrs. Repsold have introduced a great improvement. The observer sits with his back to the window of the measuring room, and light from the window is reflected from a mirror, D, made of silvered ground glass, and thence to a mirror at the back of the base-plate, the centre of which mirror is in the axis of the microscope, and inclined to it at an angle of 45°. From the latter mirror the light passes through a lens, which is fixed in the centre of the base-plate, and thence to the photographic plate. This illumination is remarkably uniform over the field and very suitable for accurate work, whilst the observers' eyes are shaded from the direct light of the window. It is indeed a substantial practical benefit, and the observers do not complain of the strain on the eyes as they did when they worked facing the light.

The details of the micrometer microscope are better seen in Plate 3.

The whole of the micrometer work is mounted on a steel tube which has been turned truly cylindrical, and slides very smoothly in bearings inside the cast-iron supporting tube, in which it can be firmly clamped by the screws 1 and 2.

The mounting of the object-glass slides inside this steel tube, its position inside the steel tube being adjusted and defined by the screw whose divided head is shown at 3. The screw which moves the steel tube inside the iron supporting tube is hidden in the plate by the micrometer-box.

The micrometer-box is double. The lower half contains the slides for movement of the upper box with respect to the tube by means of the undivided heads 4 and 5. The upper box contains

the square of fixed webs with their adjustments, and the slides, which are moved by the screws with graduated heads 6 and 7.

8 and 9 are the screws the ends of which form the end bearings of the micrometer screws, and by which the readings for coincidence of the movable webs with the fixed wires are reduced to zero.

10 and 11 move slides which enable the eyepiece to be centred over any part of the field. In ordinary work the lowest power eyepiece (shown in the plates) is used, with its axis in coincidence with that of the microscope tube, and having the whole fixed square within its range of sharp vision. In adjustment of the reading for coincidence and determination of run a much higher power is employed, and it is then only that the screws 10 and 11 are used.

13 is a small graduated circle attached to a hollow block which screws into the eyepiece slide. The eyepiece screws home into this hollow block; the readings of the graduated circle enable the observer to set his eyepiece-adjustment to the mean of several measures for focus of the eyepiece on the webs or on the image of the plate. When the focus of the eyepiece has been adjusted it can be clamped at the required reading by means of the screw 14.

The indices of the micrometer screw-heads are placed at the back, so that the screw-heads are read by reflection from the mirrors 15 and 16. These mirrors have adjustments which permit the micrometer readings to be made either by the microscope observer or by the clerk. Some observers prefer one method, some the other.

The graduations and figures of the micrometer-heads are engraved on celluloid; the jet black divisions and figures on the dull white surface are read with great ease and precision.

The instrument is equally perfect optically and mechanically, and has in every way more than realised my expectations. I gratefully acknowledge the skill and care, both in workmanship and design, with which Messrs. Repsold have carried out my general plans.

Note on the Effect of Wear on the Errors of Micrometer Screws. By David Gill, C.B., LL.D., F.R.S. Her Majesty's Astronomer at the Cape of Good Hope.

In the *Monthly Notices*, vol. xlv. p. 81, the writer gave an account of the systematic errors produced by wear in the readings of the Circle microscopes of the Cape Transit Circle. The original screws of the Circle microscopes were of gun-metal, and were in use from 1855 till 1879, when, for reasons detailed in the above-mentioned paper, it was found necessary to have new screws made. In 1880 the errors of these new gun-metal screws were rigorously investigated and found to be practically insignificant (*loc. cit.* p. 66). In 1884 September the errors of these screws were again investigated, and were found to be very considerable (*loc. cit.* p. 68). The origin of these errors is clearly traced to wear, and an elaborate discussion is given, based on the determinations of run at different screw-readings, by which corrections of the screw errors were determined for 10 epochs between 1880 January and 1884 December, and these corrections were duly applied to the observed results in the formation of the declinations of the Cape Catalogue for 1885 (*Cape Meridian Observations*, 1882–84, Introduction, pp. vi–xxi).

It was evident, however, that gun-metal screws working in brass bearings were liable to a very large amount of wear, and in 1885, before the observations for the Cape Catalogue for 1890 were commenced, a new set of steel screws was made by Messrs. Troughton and Simms. The numbering of the graduations of three of the six drum-heads was reversed in direction, and the boxes of the three corresponding micrometers were also reversed, as had already been done at Greenwich. In this way the wear of the screw-threads, resulting from the pressure of the opposing spring, creates errors which have opposite effects on the Circle readings, according as increasing readings of the head correspond with increased or diminished compression of the spring (*loc. cit.* p. 81).

The errors of these new steel screws were investigated in 1886 with the apparatus and in the manner described in the paper above quoted, and were again investigated in 1897. The results, in seconds of arc, are given in the following tables :—

Corrections for Inequalities in whole Revolutions of Microscope-Micrometer Screws.

Micr.	$9^{r}\cdot0$ 1886.	$9^{r}\cdot0$ 1897.	$0^{r}\cdot0$ 1886.	$0^{r}\cdot0$ 1897.	$1^{r}\cdot0$ 1886.	$1^{r}\cdot0$ 1897.	$2^{r}\cdot0$ 1886.	$2^{r}\cdot0$ 1897.	$3^{r}\cdot0$ 1886.	$3^{r}\cdot0$ 1897.	$4^{r}\cdot0$ 1886.	$4^{r}\cdot0$ 1897.	$5^{r}\cdot0$ 1886.	$5^{r}\cdot0$ 1897.	$6^{r}\cdot0$ 1886.	$6^{r}\cdot0$ 1897.
	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
A	0·00	0·00	+0·02	+0·16	+0·09	+0·25	+0·11	+0·27	+0·12	+0·23	+0·09	+0·17	+0·03	+0·07	0·00	0·00
B	0·00	0·00	+ ·01	− ·07	+ ·01	− ·19	00	− ·31	− ·04	− ·34	− ·06	− ·29	− ·05	− ·14	0·00	0·00
C	0·00	0·00	− ·04	− ·23	− ·04	− ·27	− ·02	− ·22	− ·03	− ·21	− ·03	− ·11	− ·04	− ·07	0·00	0·00
D	0·00	0·00	+ ·06	+ ·22	+ ·07	+ ·37	+ ·06	+ ·49	+ ·06	+ ·39	+ ·04	+ ·37	+ ·01	+ ·31	0·00	0·00
E	0·00	0·00	+ ·08	+ ·22	+ ·16	+ ·38	+ ·24	+ ·44	+ ·17	+ ·43	+ ·14	+ ·32	+ ·07	+ ·03	0·00	0·00
F	0·00	0·00	− ·17	− ·17	− ·37	− ·53	− ·52	− ·63	− ·52	− ·57	− ·45	− ·47	− ·27	− ·33	0·00	0·00
Mean	0·00	0·00	−0·01	+0·02	−0·01	0·00	−0·02	+0·01	−0·04	−0·01	−0·05	0·00	−0·04	−0·02	0·00	0·00

Corrections for Periodic Error of Microscope-micrometer Screws.

Micr.	r ·0 1886.	r ·0 1897.	r ·1 1886.	r ·1 1897.	r ·2 1886.	r ·2 1897.	r ·3 1886.	r ·3 1897.	r ·4 1886.	r ·4 1897
	″	″	″	″	″	″	″	″	″	″
A	−0·04	+0·01	−0·05	+0·01	−0·02	−0·01	0·00	−0·03	−0·02	−0·03
B	+ ·01	+ ·01	− ·06	− ·01	− ·07	− ·02	− ·07	− ·04	− ·09	− ·05
C	− ·01	+ ·02	− ·04	− ·01	− ·06	− ·04	− ·06	− ·05	− ·02	− ·05
D	− ·06	+ ·01	− ·09	·00	+ ·02	·00	+ ·10	·00	+ ·01	− ·01
E	− ·03	+ ·01	− ·05	− ·01	− ·01	− ·01	+ ·02	− ·01	·00	− ·02
F	− ·02	− ·01	− ·01	·00	+ ·01	·00	+ ·01	·00	− ·01	·00

Micr.	r ·5 1886.	r ·5 1897.	r ·6 1886.	r ·6 1897.	r ·7 1886.	r ·7 1897.	r ·8 1886.	r ·8 1897.	r ·9 1886.	r ·9 1897.
	″	″	″	″	″	″	″	″	″	″
A	−0·03	−0·01	+0·01	+0·02	+0·06	+0·02	+0·07	+0·01	+0·02	+0·01
B	− ·08	− ·03	− ·01	+ ·01	+ ·11	+ ·05	+ ·16	+ ·06	+ ·11	+ ·03
C	+ ·03	− ·03	+ ·06	+ ·01	+ ·05	+ ·04	+ ·03	+ ·06	+ ·01	+ ·05
D	− ·12	− ·02	− ·12	− ·02	+ ·04	·00	+ ·16	+ ·02	+ ·09	+ ·02
E	− ·04	− ·02	− ·03	− ·01	+ ·03	+ ·01	+ ·07	+ ·03	+ ·04	+ ·03
F	− ·01	+ 01	+ ·01	+ ·01	+ ·02	+ ·01	+ ·01	·00	− ·01	− ·01

Now the micrometers in which the readings of the head diminish as the wire approaches the head (*i.e.* as the pressure of the counter spring increases) are A, D, and E, whilst the micrometers B, C, and F are those in which the readings of the heads increase as the wire approaches the head. The effects of ten years' wear on the non-periodic errors of the screws are shown below :—

		0^r	1^r	2^r	3^r	4^r	5^r
		″	″	″	″	″	″
Increased readings correspond to increase of pressure of spring	B	−0·09	−0·20	−0·31	−0·38	−0·35	−0·09
	C	−0·27	−0·31	−0·24	−0·24	−0·14	−0·03
	F	−0·34	−0·16	−0·11	−0·05	−0·02	−0·06
		″	″	″	″	″	″
Increased readings correspond to diminished pressure of spring	A	+0·14	+0·16	+0·16	+0·11	+0·08	+0·04
	D	+0·16	+0·30	+0·43	+0·33	+0·33	+0·28
	E	+0·14	+0·22	+0·20	+0·26	+0·18	−0·04

These results prove conclusively :—

(1) That the wear of steel screws in brass bearings is very much less than that of gun-metal screws in brass bearings.

(2) That even when steel screws are employed the changes produced by wear in the non-periodic corrections are very marked.

(3) That by reversing the direction of pressure of the counter

springs in half of the screws, the effect of wear on the mean of the micrometer readings is practically eliminated.

(4) That the effects of wear have a slight tendency to diminish the original periodic errors of the screws.

On a probable Instance of periodically recurrent Disturbance on the Surface of Jupiter. By W. F. Denning.

I wish to call the attention of observers of *Jupiter* to the desirability of carefully examining the northern hemisphere of the planet in the mornings of 1901 February to ascertain whether there occurs or has recently occurred any striking outbreak of spots on the north temperate belt in about latitude $+25°$. At intervals of little more than ten years phenomena of this kind apparently affect this region, and in the suddenness of their formation and development, as well as in their rapidity of motion, they furnish greater extremes than have been witnessed in any other latitude of the planet.

When in the autumn of 1880 I observed the north temperate belt with a string of dark spots upon it (*Monthly Notices*, 1880 November, p. 46) I remembered that the same features had been presented in 1870 and 1871. In 1891 I reobserved them, and found the velocity of the spots slower than in 1880 (*Observatory*, 1891 October, p. 330). But it may be as well to allude briefly to the several phenomena which have led me to take up the view of their periodicity.

1850 March 27.—Mr. W. Lassell observed *Jupiter* with a power of 430 on his 24-inch reflector and made a drawing of the planet (*Monthly Notices*, 1850 April), which included two marked projections from the S. edge of the N. temperate belt.

1860 February 29.—Mr. J. W. Long, F.R.A.S., observing *Jupiter* with a 5-inch refractor, power 305, noticed a curious streak or oblique belt lying between the N. temperate belt and the N. equatorial belt. The object was examined by Mr. J. Baxendell, of Southport, on March 2, 5, 7, and several subsequent occasions; and he found that it "increased greatly in size and darkness," and became much extended in longitude, though the latitude of the extremities remained the same. When first seen on February 29 the streak ranged over about 7° in longitude, but by April 9 it had reached more than half round the disc. On May 3 it had spread itself over the complete circumference of the planet, and on May 6 the two ends considerably overlapped. Mr. Baxendell estimated on several dates the times of transit of the p. and f. ends across the planet's central meridian, and I have obtained some additional ones of both the ends and the centre from their positions on a series of drawings published in *Monthly Notices*, 1860 April, and in the *Proceedings* of the Lit. and Phil.

Society of Manchester for the same month. From these data I obtain the following rates of rotation of the slanting belt:—

	Period h m s	
South preceding end	9 52 13	163 Rotations
Middle of the belt...	9 54 7	163 ,,
North following end	9 56 1	162 ,,

These values show a difference of $3^m\ 48^s$ in the relative times of the p. and f. ends. This is equivalent to $9^m\ 13^s$ in a terrestrial day, and proves that in sixty-four days (February 29 to May 3) the belt would distend itself completely round the planet, as was actually observed.

I believe that the outburst or eruption of dark material originated in the N. temperate belt,* and that its initial violence was such that it was forced in a direction southwards, the rapid rotatory movement of the planet being quite incapable at first of distending it in longitude. But immediately afterwards the effects of rotation became obvious, and the short belt, lying at first nearly N. and S., lengthened out, became less oblique, and finally, after an interval of sixty-four days, was transformed into one of the normal bands of the planet. Mr. Baxendell states that on April 20 the belt was of a remarkable bluish-black colour, and that condensations marked the ends and middle of it. The rate of velocity of the S. p. end appears to have increased rapidly with the time.

1870 August 12.—Very little alteration occurred in the dusky N. temperature belt during the opposition of 1869, but at the reappearance of *Jupiter* (1890 July) marked changes took place, according to Mr. Gledhill. On August 12 he noted that the belt appeared very rugged. On September 24 he observed and drew five well defined dark spots upon it (*Astronomical Register*, 1871). On November 25 Mr. J. Birmingham says it exhibited two dusky patches not previously seen. At a later period Mr. Gledhill noted some dark condensations both from its N. and S.

* I am led to this view by the fact that the motion of the streak where it joined the N. edge of the N. equa. belt was characteristic of the great velocity of the current forming the N. temp. belt. It is true that the f. end of the slanting belt where it combined with the N. temp. belt moved very slowly; but this appears to me to afford strong proof that it was the material ejected which exhibited the greatest velocity of rotation, and not the actual seat of disturbance. If we regard the place of the latter as really represented by the N.f. end of the streak, and the disturbance as occasioned by a durable uprush from *Jupiter's* surface, then the true rotation period of the globe of the planet would be as nearly as possible $9^h\ 56^m$, as found by Cassini from Hooke's great southern spot of 1664, 1665, and following years. This conclusion is strengthened by the fact that the motion of the N.f. end of the streak was equable during the whole period, whereas the S.p. end and middle exhibited an increasing velocity. The variable rate of speed in the western part of the streak sufficiently showed that it could not have been actually joined to the solid globe of the planet, but probably consisted of material floating rapidly along in a region far above the surface.

sides. In an article on "Telescopic Work" which I contributed to the *English Mechanic* of 1871 January 13 I included two drawings made by Mr. H. M. Whitley, of Truro, with a 6½-inch reflector in the autumn of 1870, and these show several well pronounced spots on the same belt. A drawing by Mr. James Cook, of Preston, with a 10-inch reflector on 1871 January 8, displays five spots in this latitude, which must evidently have been in a condition of great disturbance at this particular epoch.

1880 October 17.—Two black spots separated by 20° of longitude were detected by Mr. F. C. Dennett, of Southampton, on the N. temperate belt, which he describes as of a blue colour. These objects were seen by me at Bristol on October 24, and were closely watched during ensuing months. New spots were formed, and on December 30 I found they were spread over 270° of longitude. At the middle of 1881 January, after a visibility of ninety days, they quite encircled the planet and soon lost their distinctive character to form a new belt immediately south of the one on which they originally appeared. The rotation period of two of the principal spots was $9^h 48^m$. The disturbance was a striking one, and attracted widespread attention during its progress.

1890 October–November.—A considerable number of small black spots appeared at the close of the opposition of 1890 on the narrow belt about 9″ N., according to Mr. E. E. Barnard. When in the following year the planet favourably reappeared the spots had enlarged and were quite noticeable. One was seen by Mr. A. S. Williams on 1891 May 14, another by Mr. Barnard on July 11. In August I detected them, and on the 21st saw one which was quite as dark and prominent as a satellite-shadow when projected on the disc of *Jupiter* (*Observatory*, 1891 September, p. 312). I found the rotation period of one of the spots $9^h 49^m 27^s$; but the velocity slackened at the middle of September, and became $9^h 49^m 44^s$, according to Mr. A. S. Williams. The markings were seen by many observers, and some good photographs of them were obtained at the Lick Observatory.

I believe from the foregoing summary, incomplete as it is, that a fair case has been made out for further investigation. During the present year (1898) the N. temperate belt has been lying quiescent and extremely feeble in tone, for its aspect has been simply that of a delicate pencil shading, somewhat narrow, but in the usual position. This faintness may be only the prelude to the reintensification which we are fairly entitled to expect during the ensuing two years. But at the particular time antedating the periodical outbreaks to which I have been alluding the belt has not been consistently weak. In 1869 it was notably dark, and had actually become fainter in 1870, when numerously beaded with spots.

If the latter are periodically recurrent, as I assume from past observations, the intervals may not be always identical, for it is very possible there may be minor outbreaks or disturbances in the

decade intervening between two maxima. In 1870–71, and again in 1890–91, the evidences of unusual activity in the belt remained visible for a long time, probably a year or more; but the recorded observations neither enable us to determine the length of the whole period or the precise dates of its earliest cyclical presentations. The evidence roughly indicates a period of 10·2 years, but it remains for future observation to finally affirm the fact of its occurrence and to accurately define the interval. Even if additional data fail to corroborate the views here formulated we shall at least have advanced a step nearer the truth, and shall be the more ready to relinquish our vague ideas as to distinctly periodical changes on *Jupiter*. For my own part I shall be willing to admit that many of his atmospheric features, though undoubtedly far more durable than our own, yet display many similar vagaries. I do not, however, anticipate that future experience will furnish a negative, but that when the planet is examined, either at a late period in the opposition of 1900 or at the earliest time in that of 1901, the north temperate belt will exhibit a similar disturbance to that which has marked it in the closing year of each of the last five decades. It is perhaps unfortunate that *Jupiter* will be in conjunction with the Sun in 1900 December, and that quite possibly the expected phenomena may in a great measure escape record. If *Jupiter* had been in conjunction in 1860 March and 1880 November the remarkable transformations of the belt which occurred at those epochs would never have become matters of history. It is to be expected, however, that, in the event of a well defined recurrence, the evidences of it will be favourably visible in the spring and summer of 1901. The duration seems to be very variable, for its chief intensity lasted about two months in 1860, three months in 1880, and certainly more than twelve months at its last apparition in 1890–91.

Bristol:
1898 *November* 30.

The Extra-equatorial Currents of Jupiter during the Apparition of 1897–98. By Rev. T. E. R. Phillips.

(*Communicated by W. F. Denning.*)

The following is a short discussion of the chief spots and currents visible on *Jupiter* during the last apparition outside the equatorial regions, omitting the three dark spots on the N. tropical zone which have been already discussed by Mr. Denning in the *Observatory* (May and September numbers).

Including the red spot, six distinct currents are denoted below, and it is noteworthy that only in the cases of the north north temperate belt, and, perhaps, a belt still further north

(not included in this discussion), was the rotation period equal in length to that of the red spot.

As has been shown by Mr. A. Stanley Williams in his paper "On the Drift of the Surface Material of *Jupiter* in different Latitudes," *Monthly Notices*, R.A.S., vol. lvi. No. 3), the various Jovian currents are by no means symmetrically arranged. In particular, there is a striking difference in the sequence of currents in the N. and S. hemispheres. The N. hemisphere contains in close contiguity both the slowest and swiftest Jovian currents known, though the latter was not apparent last apparition owing to the absence of spots and other observable markings in that latitude. The slowest current detected on the disc was in latitude about $+33°$, its rotation period being $10^{s}\cdot4$ longer than the period of System II. (Mr. Crommelin's *Ephemeris for Physical Observations of Jupiter*), and $25^{s}\cdot7$ longer than that of the N. tropical zone, which Mr. Denning found to be $9^{h}\ 55^{m}\ 26^{s}\cdot3$. On the other hand, in the S. hemisphere, with the exception of the red spot, the periods of the various currents seem to diminish gradually from the S. equatorial belt towards the pole, though a determination of the velocity of the surface material further S. than latitude $-40°$ was not made last apparition through the absence of markings sufficiently definite and distinct to enable their transit times to be taken.

In this investigation of the extra-equatorial currents valuable assistance has been received from Mr. W. F. Denning, F.R.A.S., Mr. A. S. Williams, F.R.A.S., and Mr. J. Gledhill, F.R.A.S.

The following tables for the most part explain themselves. After the title of each current will be found a statement of the *estimated* latitude, and the mean value of its rotation period (R). Observations of the individual spots follow headed by their adopted periods. The third column (O—C) contains the residuals or differences between the observed and computed positions according to the adopted period, and thus shows at a glance how far that period satisfies the series of observations.

The following is the explanation of Mr. Williams's system of abbreviations employed in the column for "remarks":—

S = small.	vB = very bright.
vS = very small.	mB = moderately bright.
eS = exceedingly small.	F = faint.
D = dark.	vF = very faint.
B = Bright.	eF = exceedingly faint.
eB = exceedingly bright.	eeF = most exceedingly faint.

Dark Streaks on North North Temperate Belt.

Latitude about $+33°$. Mean $R = 9^{h}\ 55^{m}\ 52^{s}\cdot0$.

Two long dark spots or streaks were observed on this belt, both of which exhibited periods considerably longer than that of System II.

Streak I. $R = 9^h\ 55^m\ 53^s \cdot 4$.

Accurate observations of this streak were somewhat difficult to obtain, especially towards the close of the apparition, when it seemed to lose much of its definiteness of outline, and to become somewhat vague and diffuse. It was considerably longer and more diffused than streak II. in this latitude. The periods of the *preceding end* and *centre* of this streak were computed separately, but being practically identical, the period here adopted is the mean of the two results. The difference of longitude between the p. end and centre is allowed for in the following table :—

Date.	Longitude (System II.).	O–C.	Observer.	Remarks.
1898.	°	°		
April 15	55·6	−2·8	Phillips	Centre.
25	53·7	+4·3	,,	Prec. End.
27	46·9	−3·1	,,	,,
30	52·0	+1·1	,,	,,
30	65·8	+2·8	Williams	Centre.
May 4	49·1	−3·1	Phillips	Prec. End.
12	57·0	+2·5	Denning	,,
31	60·6	0·0	Phillips	,,
31	72·7	+0·1	,,	Centre.

Streak II. $R = 9^h\ 55^m\ 50^s \cdot 7$.

March 21	265·5	−1·2	Phillips.	
28	267·8	−0·6	,,	
April 5	272	+1·7	Nijland.	
7	267·5	−3·4	Denning.	
12	277·0	+4·9	Phillips.	
17	268·8	−4·5	Denning.	
17	276·0	+2·7	Phillips	Length = 9°·7
19	275·3	+1·5	Williams.	
19	274·1	+0·3	Denning.	
22	271·3	−3·2	,,	
May 6	277·1	−0·9	,,	
6	279·6	+1·6	Phillips.	
16	281·6	+1·2	Denning.	
18	279·6	−1·3	,,	
18	280·1	−0·8	Phillips.	
28	281·9	−1·4	,,	
June 4	285·0	0·0	,,	
16	288·0	0·0	Denning.	
28	291·8	+0·9	,,	
July 3	294·1	+2·0	,,	

Note.—There was a marked intensification or condensation of the dark material on a belt in lat. about +39°. Several transits were taken, but, owing to the increasingly ill defined character of the marking and the great

difficulties in the way of securing accurate observations, the discordances were so great that any determination of the period must necessarily be uncertain and unreliable. This object has therefore been omitted from the present discussion.

"*The Red Spot.*"

This spot, except at its s.f. end, was again very faint and difficult. At times, when the seeing was good, the complete oval outline could be distinctly made out, but as a rule the boundary of the p. end was difficult to determine with certainty. The region n.p. and p. the spot was exceedingly brilliant, and possibly this, by an effect of irradiation, may *partly* account for the apparent displacement of the spot towards the f. end of the well-known "bay" or hollow in the S. equatorial belt in which it lies. To the writer the spot appeared to transit the c.m. about three minutes later than the centre of the "bay," and as Mr. Denning also calls attention to the displacement, and some indication of the same appearance is furnished by Mr. Gledhill's figures published in the supplementary number of the *Monthly Notices* of the R.A.S., vol. lviii. No. 9, there seems every probability that the displacement of the spot towards the f. end of the "bay" was an objective reality, though irradiation, together with the less prominent character of the p. "shoulder" compared with that following the spot, may have caused such displacement to appear somewhat exaggerated.

Throughout the apparition the red spot was in contact with the S. temp. belt.

As regards the colour of the spot the general opinion of observers seems to be that almost all trace of red had disappeared. To the writer the colour appeared distinctly grey.

During the past apparition of the planet the red spot exhibited a still further increase in the length of its rotation period. $R = 9^h\ 55^m\ 42^s \cdot 1$.

Date.		Longitude (System II.).	O−C.	Observer.	Remarks.
1898.		°	°		
March	5	21·8	+0·2	Williams.	
	15	21·2	−0·8	MacEwen.	
	22	22·7	+0·5	Williams.	
	22	23·6	+1·4	Denning.	
	29	21·1	−1·4	Williams.	
	29	23·1	+0·6	Phillips	A grey oval ring, darker sf.
	31	22·4	−0·1	Williams.	
April	1	22·4	−0·2	MacEwen.	
	5	23·3	+0·6	Williams.	
	5	23·6	+0·9	Gledhill.	

Date.		Longitude (System II.).	O–C.	Observer.	Remarks.
1898. April	8	22°·8	0°·0	Williams.	
	8	23·4	+0·6	Gledhill.	
	12	20·0	−3·0	Williams.	
	15	21·3	−1·8	"	
	15	22·6	−0·5	Denning.	
	15	24·8	+1·7	Phillips.	
	17	21·0	−2·1	Williams.	
	17	23·6	+0·5	Denning.	
	17	23·6	+0·5	Phillips	Very bright n.p
	18	25·2	+2·0	Denning.	
	22	24·9	+1·6	"	
	22	21·4	−1·9	Williams.	
	25	24·7	+1·3	Phillips.	
	27	22·4	−1·1	Williams.	
	27	25·1	+1·6	Phillips	Grey oval shading, gradually darkening to s.f.
	30	24·8	+1·2	"	
May	4	25·1	+1·4	Gledhill.	
	4	25·4	+1·7	Williams.	
	9	21·6	−2·3	"	
	12	24·1	+0·1	Gledhill.	
	14	23·8	−0·3	"	
	14	24·1	0·0	Denning.	
	14	25·1	+1·0	Williams.	
	28	25·0	+0·4	Gledhill.	
	31	24·8	+0·1	"	
June	7	25·9	+0·9	Denning.	
	7	26·4	+1·4	Williams.	
	7	29·4	+4·4	Phillips.	
	10	23·6	−1·5	Gledhill.	
	12	23·8	−1·3	"	
	12	28·7	+3·6	Denning.	
	14	24·3	−0·9	Gledhill.	
	17	25·6	+0·3	"	
	19	27·4	+2·0	Phillips.	
	24	25·3	−0·3	Gledhill.	
July	11	23·8	−2·4	"	
	13	24·4	−1·8	"	
	13	24·6	−1·6	Denning.	
	30	30·1	+3·2	"	

White Spots on South Tropical Zone.

Three spots were observed sufficiently well to enable a determination of the value of R to be made.

Latitude about -20°. Mean R $=9^h\ 55^m\ 25^s{\cdot}6$

Spot I. R $=9^h\ 55^m\ 34^s{\cdot}4$.

Date.		Longitude (System II.)	O−C.	Observer.	Remarks.
1898.		°	°		
April	13	58·2	−1·1	Phillips	Spot seen and drawn on March 22 connected by rift with rift in S. E. B.
	13	58·3	−1·0	Williams	S, F, not well defined; irregular in shape and brightness. A narrow, bright rift ran n.f. from it through S band of S. E. B.
	15	59·8	+0·9	„	vS, F, rift n.f. glimpsed.
	15	64·2	+5·3	Booth.	
	25	57·4	0·0	Phillips.	
	30	56·7	0·0	Williams	S, F, ill defined; rift n.f. not seen.

Spot II. R $=9^h\ 55^m\ 29^s{\cdot}2$.

Date.		Longitude (System II.)	O−C.	Observer.	Remarks.
1898.		°	°		
March	29	110·7	+1·3	Williams	vS, vF.
April	8	106·9	+0·3	„	„
	13	104·3	−0·9	„	vS, eeF, ill defined, very difficult.
	18	109·9	+6·1	Phillips.	
	30	100·2	−0·3	Williams	vS, F.
June	5	90·4	0·0	„	vS, vF.

Spot III. R $=9^h\ 55^m\ 13^s{\cdot}2$.

Date.		Longitude (System II.)	O−C.	Observer.	Remarks.
1898.		°	°		
April	16	166·6	+2·5	Williams	vS, F.
	30	152·2	−2·5	„	„
May	15	145·0	+0·3	„	vS, vF.
June	3	131·6	−0·4	„	„

South Temperate Spots. (Spots on S. Temp. Belt or at its S. Edge).

Mean latitude -30°. Mean R$=9^h\ 55^m\ 19^s{\cdot}4$.

Several spots were seen in this latitude, but some of them were not observed sufficiently well to enable reliable rotation periods to be deduced. They have therefore been omitted from this discussion. In the following list Spots II. and IV. might perhaps be considered as belonging to a different current. They appeared to project into the light zone S. of the S. temp. belt,

and to be affected somewhat by the more rapid rotation of the dark material still further S., thus forming a kind of intermediate or transitional current. As, however, they were clearly connected with the S. temp. belt they have been included under this heading.

Spot I. White. R = $9^h\ 55^m\ 21^s.7$.

Date. 1898.	Long. (System II.) °	O−C. °	Observer.	Remarks.
March 29	20·1	0·0	Phillips.	
April 5	19·2	+2·3	Williams	eS, eB, well defined, slightly oval, E and W.
12	12·1	−1·6	,,	vS, vB, well defined.
15	14·0	+1·7	Denning.	
15	9·2	−3·1	Williams	vS, vB, well defined.
17	8·5	−2·9	Denning.	
17	12·3	+0·9	Williams	eS, vB, well defined, slightly oval.
17	12·1	+0·7	Phillips	Very brilliant.
22	7·8	−1·3	Williams	eS, vB, well defined.
22	5·6	−3·5	Denning.	
27	4·9	−1·9	Williams	eS, vB, well defined.
May 2	4·6	+0·1	Denning.	
4	3·0	−0·6	Williams	eS, eB, very well defined, nearly round
4	6·8	+3·2	Phillips.	
14	358·1	−0·9	Denning.	
June 7	349·6	+1·6	,,	

Spot II. White. R = $9^h\ 55^m\ 11^s.5$.

Date. 1898.	Long. (System II.) °	O−C. °	Observer.	Remarks.
May 9	29·5	−0·5	Williams	eS, mB.
14	29·3	+2·8	,,	eS, mB, well defined.
June 2	12·5	−0·4	Phillips.	
7	14·3	+4·9	Williams	eS, F.
19	0·2	−0·7	Phillips.	

Spot III. White. R = $9^h\ 55^m\ 29^s.4$.

Date. 1898.	Long. (System II.) °	O−C. °	Observer.	Remarks.
March 29	110·7	0·0	Williams	vS, mB.
April 6	110·5	+1·9	Phillips.	
8	108·1	−0·1	Williams	eS, vB, nearly round.
13	105·5	−1·1	,,	eS, B, well defined.
30	101·4	−0·6	,,	eS, F.
June 5	92·4	+0·2	,,	eS, F.

Spot IV. White. $R=9^h\ 55^m\ 14^s\!\cdot\!6$.

Date.		Long. (System II.)	O–C.	Observer.	Remarks.
1898.		°	°		
April	4	170·9	0·0	Denning.	
	(13	173·4	...	Williams	vS, mB, well defined except on F side, where it expands into a broad white streak.)
	(16	170·9	...	„	vS, F.)
	30	153·7	–0·7	„	vS, B, well defined.
May	15	144·7	–0·3	Denning.	
	15	145·9	+0·9	Williams	S, B, well defined. A large and conspicuous object. Perhaps really compound, and formed of several small spots close together.
June	3	132·9	0·0	„	vS, B, well defined.

Note.—It is very uncertain whether the observations of April 13 and 16 relate to this spot at all. A comparison of these two observations with drawings made about this time seems to show that they do not.

Spot V. Dark. $R=9^h\ 55^m\ 18^s\!\cdot\!5$.

Date.		Long. (System II.)	O–C.	Observer.	Remarks.
1897.		°	°		
Dec.	30	230·1	–1·5	Phillips	Belt f. this spot broader and almost certainly double.
1898.					
April	16	180·0	+6·1	Williams	eS, D, on S.T.B.
	30	161·9	–4·4	„	eS, mD.
May	15	158·0	–0·3	„	eS, mD, elongated E. and W.
	15	150·7	0·0	Denning	P. end of thickening of belt.
June	22	129·9	–0·2	„	„ „
July	2	125·1	+0·3	„	„ „

Note.—The spot observed on 1897 December 30, following which the S.T.B. became wider and apparently double, is almost certainly identical with that which during the later months of the apparition marked the commencement of the thickening of the belt referred to by Mr. Denning. The p. end of this thickening of the belt and the centre of the spot showed the same rate of rotation, their mean difference of longitude being allowed for in the above table.

Spot VI. White. $R=9^h\ 55^m\ 20^s\!\cdot\!6$.

Date.		Long. (System II.)	O–C.	Observer.	Remarks.
1898.		°	°		
March	21	243·5	0·0	Phillips.	
May	3	221·8	–0·7	Williams	eS, mB, on S. side of *double* S.T.B. and visible in rift also.
June	1	209·6	+1·2	„	vS, mB, ill defined.

Southern Spots.

Latitude about $-40°$. Mean $R=9^h\ 55^m\ 6^s{\cdot}3$.

This region is included in Mr. A. Stanley Williams' Zone IX. ("Drift of Surface Material of *Jupiter* in different Latitudes"), and is remarkable for its rapid rotation relatively to that of the zero meridian of System II. Two definite spots were seen last apparition, and observed with sufficient frequency to enable tolerably reliable rotation periods to be computed. The considerable south latitude of the spots, however, made accurate observations of their transit times very difficult to obtain except when the seeing was good; and to this, coupled with the somewhat faint and vague character of the markings, is doubtless to be attributed some of the discordances in the following table of positions :—

Spot I. Dark Ellipse. $R=9^h\ 55^m\ 5^s{\cdot}3$.

Date.		Long. (System II.)	O–C.	Observer.	Remarks.
1898.		°	°		
March	23	177·7	0·0	Phillips	Long dusky spot S. of S.T.B. in a well-formed bay in that belt.
April	4	163·7	−3·7	„	Spot become extended in an E. and W. direction.
	16	155·3	−1·7	Denning	A short dark streak. Time very doubtful.
	16	160·1	+3·1	Phillips.	
	18	153·4	−1·8	Denning.	
	18	160·1	+4·9	Phillips	Dusky oval spot.
	19	153·8	−0·7	Denning.	
	23	153·0	+2·0	„	
	30	145·1	+0·2	Phillips	Moved very considerably to the W. Changed its position relatively to the bay in S.T.B.
May	12	139·2	+4·6	„	Very bad air. Ellipse not seen distinctly, only a vague ill-defined shading.
	15	128·1	−4·0	Williams	Time "estimated."
June	5	115·0	+1·2	Phillips	Dark ellipse now very vague and doubtful.
	10	104·1	−5·5	„	Mere suspicion of dark ellipse.
	22	97·9	−1·3	Denning.	

Spot II. Dark condensation of S.S.T.B. $R = 9^h\ 55^m\ 7^s{\cdot}4$.

Date.		Long. (System II.)	O–C.	Observer.
April	22	317·8	$-2{\cdot}0^{\circ}$	Denning.
May	4	307·0	−3·1	Phillips.
	6	307·4	−1·0	Denning.
	6	308·6	+0·2	Phillips.
	11	304·9	+0·5	„
	16	295·5	−4·9	Denning.
	16	300·7	+0·3	Phillips.
	18	292·3	−6·4	Denning.
	18	298·5	−0·2	Phillips.
	28	292·1	+1·4	„
June	4	286·2	+1·2	„
	11	279·4	+0·1	„
	16	272·9	−2·4	„
	28	259·8	−5·8	Denning.
July	5	264·9	+5·0	„

Summary of Results.

	Current.	Approx. Lat.	No. of Spots observed.	Rotation Period. h m s
1.	N.N. Temp. Belt	$+33^{\circ}$	2	9 55 52·0
2.	*N. Trop. Zone	+15	3	9 55 26·3
3.	S. Trop. Zone	−20	3	9 55 25·6
4.	"Red Spot"	−21	1	9 55 42·1
5.	S. Temp. Belt	−30	6	9 55 19·4
6.	Southern Spots	−40	2	9 55 6·3

Observations of Planet (433) (1898 DQ) *made at the Royal Observatory, Greenwich, with the* 30-*inch Reflector of the Thompson Equatorial.*

(*Communicated by the Astronomer Royal.*)

Photographs of Planet DQ were obtained with the 30-inch reflector of the Thompson Equatorial on 1898 December 7 with exposures of 3^m, 5^m, and 7^m, and on December 9 with exposures of 10^m, 6^m, 5^m, and 4^m. The 7^m and 5^m exposures on December 7 and the 6^m and 5^m exposures on December 9 of the planet and of eight or ten reference stars have been measured in the duplex micrometer, four measures being made of each image of the planet and two of each of the star-images, by two observers.

The right ascensions and declinations of the reference stars have been derived from the Karlsruhe Observations 1883–91, the Radcliffe Catalogue, 1890, and Schjellerup's Catalogue, 1865.

* Discussed by Mr. Denning in the *Observatory* for May and September.

Rectangular coordinates were computed from these and were compared with the measures, and linear corrections of the form $ax+by+c$ and $dx+ey+f$ deduced and applied to the measured coordinates of the planet and reference stars.

The apparent positions of the planet thus obtained are :—

Date.		App. R.A.	App. Dec.	Log Δ	Corr. for Par. R.A.	Corr. for Par. Dec.
	d h m s	h m s	° ′ ″		s	′
1898 Dec.	7 6 39 44	21 58 19·75	−0 49 25·6	0·1429	+0·12	+5·0
	9 5 24 41	22 2 15·06	−0 30 57·5	0·1464	+0·04	+5·0

The resulting corrections to the ephemeris given by M. Fayet in *Ast. Nach.*, No. 3530, are—

	R.A.	Dec.
	s	″
Dec. 7	+0·22	+ 9·6
9	+0·20	+10·0

The following table gives the assumed places of the reference stars and the apparent corrections obtained from the measures of the photograph :—

Name.	Mag.	Assd. R.A. 1885·0.	App. Corr. Dec. 7	App. Corr. Dec 9.	Assd. Dec. 1885·0.	App. Corr. Dec. 7	App. Corr. Dec. 9.	Authority for place.
°		h m s	s		° ′ ″	″		
−0·4296	6·0	21 55 11·95	−0·02		+0 3 11·1	−0·7		Karls. and Rad.
−1·4233	7·8	21 55 49·73	+0·07		−1 40 51·8	+0·9		Karlsruhe.
−1·4236	7·7	21 56 37·86	−0·01		−1 28 21·9	−0·2		Karlsruhe.
−1·4242	6·0	21 58 52·47	− ·05	+·18*	−1 27 44·4	+0·2	−0·2	Karls. and Rad.
−0·4303	8·0	21 59 30·20	+ ·04	+·04	−0 17 48·5	+0·7	+0·7	Karlsruhe.
−0·4304	7·8	21 59 39·18	− ·01	−·07	+0 4 10·4	−0·2	−0·2	Karlsruhe.
−1·4246	3·2	21 59 52·60	− ·04		−0 52 40·4	−0·6		Radcliffe.
−1·4249	8·3	22 0 56·60		−·07	−1 18 26·2		−0·7	Schjellerup.
−0·4307	8·	22 1 12·95	+ ·02	−·03	+0 0 30·5	−0·3	+0·7	Radcliffe.
−0·4310	8·4	22 2 46·71		−·21	−0 30 2·5		0·0	Schjellerup.
−1·4255	8·7	22 3 2·55		+·18	−1 33 36·5		+0·4	”
−0·4314	8·9	22 3 30·51		+·08	+0 7 33·2		−2·0	”
−0·4317	8·9	22 5 22·09		−·05	−0 6 53·2		+1·0	”
1·4262	8·3	22 5 57·72		−·04	−0 55 41·8		+0·2	”

Approximate centre of plate.

	R.A. 1885·0.	Dec. 1885·0.
	h m s	° ′
Dec. 7	21 58 6	−0 55
9	22 2 3	−0 50

Royal Observatory, Greenwich:
1898 *December* 13.

* Image large and elongated, with coma, making estimation of true centre difficult.

Observations of Comet i 1898 (Brooks) made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The following observations were made with the Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power, 55.

Greenwich Mean Solar Time.	Observer.	☄ − ✱ R.A.	Corr. for Refraction.	Log Factor of Parallax.	☄ − ✱ N.P.D.	Corr. for Refraction.	Log Factor of Parallax.	No. of Comps.	Apparent R.A. of Comet.	Apparent N.P.D. of Comet.	Comp. Star.
1898. d h m s		m s	s		′ ″	″			h m s	° ′ ″	
Nov. 14 5 39 52	H. F.	−0 1·25	+0·02	9·4462	−12 6·0	−0·3	0·8208	6	17 58 23·16	85 56 50·9	*a*
14 5 39 52	"	−3 25·47	+0·01	9·4462	− 2 37·5	−0·1	0·8208	6	17 58 23·88	85 56 46·5	*b*
18 6 2 3	G. B.	−1 25·30	+0·01	9·4900	− 2 41·3	−0·2	0·8404	3	18 4 38·62	90 38 1·2	*c*

Notes.

These observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

November 18.—Comet very faint.

The initials H.F., G.B., are those of Mr. Furner and Mr. Bischlager respectively.

Comparison Stars.

	Star's Name.	Assumed R.A. 1898·0.	Assumed N.P.D. 1898·0.	Authority.
		h m s	° ′ ″	
a	B.D. +3° No. 3574	17 58 21·96	86 9 1·0	Albany Astr. Gesell. Catalogue 6058; with PM −ˢ·01 in R.A.
b	W.B. XVII. 1264	18 1 46·90	85 59 28·4	" " " 6088
c	Lalande, 33391	18 6 1·35	90 40 46·1	Radcliffe (1890), 4752; with PM −ˢ·0022 +″·10

A photograph of Comet *i* 1898 (Brooks) was taken on November 22 at the principal focus of the 30-inch reflector of the Thompson Equatorial. The focal length of this mirror is 11 feet 3 inches. Three exposures were given of 150^s, 210^s, and 300^s. The coordinates of two of the images (210^s and 300^s exp.) of the comet and of six reference stars were measured in the same way as the astrographic plates. The means of the measures of the two images were taken.

The method of reduction was that described in the *Monthly Notices* for 1898 November, vol. lix. p. 20. The apparent place of the comet for the date of the photograph was thus found to be:—

Greenwich M.S.T.	Observer.	Apparent R.A.	Apparent Dec.	Log Δ.	Corr. for Parallax. R.A.	Corr. for Parallax. Decl.
d h m s		h m s	° ′ ″		s	″
Nov. 22 5 26 2	C.D.	18 9 7·19	−4 30 6·3	0·1020	+0·23	+5·7

The following table gives the assumed right ascensions and declinations of the reference stars, with their apparent corrections from the measures of the images:—

Star's Name.	Mag.	Assumed R.A. 1885·0.	Apparent Correction.	Assumed Decl. 1885·0.	Apparent Correction.	Authority for Assumed Place of Star.
°		h m s	s	° ′ ″	″	
B.D. −4·4415	7·6	18 7 5·55	−0·06	−4 2 25·6	+0·8	Radcliffe (1890) and Karlsruhe observations.
−5·4602	7·8	18 8 21·35	+0·05	−5 36 25·5	+0·4	Karlsruhe observations.
−5·4608	7·8	18 9 26·05	−0·01	−5 30 33·9	−0·9	Radcliffe (1890) and Karlsruhe observations.
−4·4438	7·5	18 12 54·66	−0·01	−4 8 59·8	+0·4	Radcliffe (1890) and Karlsruhe observations.
−5·4624	8·0	18 13 9·80	−0·04	−5 31 55·4	+0·3	Karlsruhe observations.
−5·4627	7·5	18 13 40·55	+0·07	−5 0 32·0	−1·0	Karlsruhe observations.

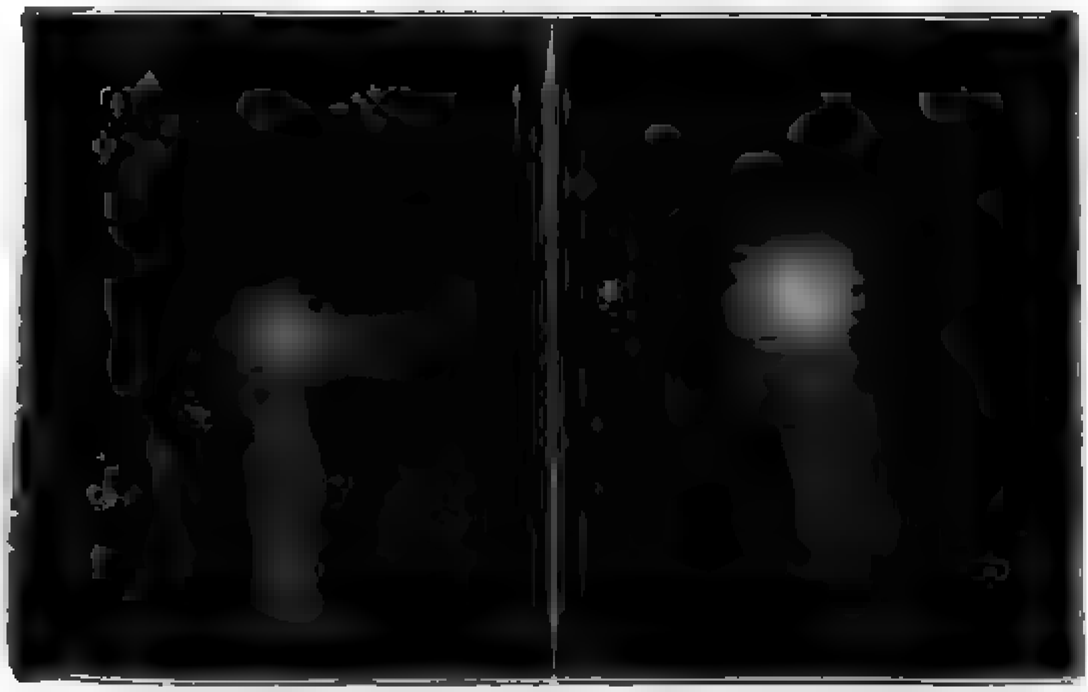
Royal Observatory, Greenwich:
1898 *December* 8.

Discovery of Comet Brooks, 1898. By William R. Brooks, M.A., D.Sc.

While sweeping the northern heavens with the 10-inch equatorial refractor in the early evening of October 20 I discovered a new comet. It was in the constellation *Draco*, and its position at 7h standard, or 75th meridian time, was R.A. $14^h\ 35^m\ 10^s$, declination north [illegible]. The cometary character of the object was at once detected, and a few minutes only were required to detect its motion, which was found to be rapid and in a south-easterly direction. The comet was quite large, round, with bright central condensation, and at times a minute stellar nucleus was noted. This was best seen with magnifying powers of 80 and 120 diameters. The comet bore magnifying well.

The comet being circumpolar, I was fortunate to secure a second observation the same night in the morning hours through breaks in the clouds. Its position, October 20, at 17^h was R.A. $14^h\ 45^m$ [illegible]; declination north [illegible].

The evening of October 21 was cloudy, but on October 22 the comet was at once picked up in bright moonlight, and at $7^h\ 12^m$ in R.A. $15^h\ 22^m\ 30^s$, declination north $55°$ [illegible]. It was intrinsically brighter than at discovery, being a conspicuous object in the 10-inch refractor, and easy in the 3-inch finder in the



November 11. November 15.

Telescopic Views of Comet Brooks, 1898.

presence of a half Moon. It was next observed on the morning of October 24, at [illegible], in R.A. [illegible], decl. north $49°\ 13'$. The full Moon soon interfered with observations. In

the meantime the comet's perihelion passage was computed to occur on November 23, but the comet was moving farther away from the Earth. On the evening of November 2, at $6^h\ 40^m$, the comet was observed in R.A. $17^h\ 20^m\ 40^s$, decl. north $25°\ 11'$, when it appeared brighter than at the last observation, and the first glimpse of a broad short tail was noted.

On November 11, when the comet was in R.A. $17^h\ 52^m\ 40^s$, decl. north $7°\ 54'$, two tails were plainly seen nearly at right angles to each other. The more prominent one was pointed away from the Sun, the second tail to the northward. A drawing of the comet is herewith given as it appeared on this occasion, and another drawing showing its appearance on the evening of November 15, when only one tail was visible with the optical power at my command, and that pointing away from the Sun. The comet's position on this date, November 15, at $7^h\ 14^m$, was R.A. $18^h\ 0^m\ 40^s$, decl. north $2°\ 33'$. The comet at its brightest was just visible to the naked eye, and readily picked up with a good opera or field glass.

As a matter of record in the enduring archives of the Royal Astronomical Society, may I be allowed to say that I have now been permitted to reach "my majority" in cometary discovery, this latest comet being my twenty-first? Thirteen of these were made with reflecting telescopes, of my own construction, of 5 and 9 inches aperture respectively. The remaining eight comets were discovered with the 10-inch equatorial refractor of this observatory.

Smith Observatory, Geneva, New York, U.S.A.:
1898 November 26.

Observations of Comet Coddington (*c* 1898). By John Tebbutt.

I have much pleasure in transmitting observations of comet *Coddington* (*c* 1898), comprising 67 nights' work, from 1898 June 15 to October 18. They were made with a square bar-micrometer on the 8-inch equatorial. The differential coordinates are corrected for errors in the orientation and form of the micrometer, and for the comet's proper motion, but not for refraction, which was hardly sensible. The comet was small throughout, with a condensation in its centre, and admitted of pretty accurate observations. The concluded values of R.A. and N.P.D. are uncorrected for parallax. I fear the comet will be too faint for re-observation after the full Moon; but should I succeed in picking it up again I will forward the observations in due time.

1898.	Windsor Mean Time.	Comet—Star. R.A.	Comet—Star. N.P.D.	No. of Comps.	Comet's Apparent R.A.	Comet's Apparent N.P.D.	Comp. Star.
	h m s	m s	′ ″		h m s	° ′ ″	
June 15	8 26 27	− 4 54·64	− 9 56·0	2	16 14 3·18	117 16 5·3	1
16	7 39 35	− 1 19·81	+ 4 50·8	12	16 10 42·42	117 52 26·1	2
17	8 48 9	− 5 0·14	+ 9 45·0	[illegible]	16 7 2·51	118 31 32·1	3
22	8 27 41	− 0 33·11	+ 2 46·6	8	15 49 19·75	121 32 16·3	4
24	6 35 26	− 0 53·56	+ 8 49·4	15	15 42 27·55	122 38 48·9	5
25	7 2 43	− 2 51·60	+ 2 6·9	10	15 38 48·81	123 13 10·8	6
25	7 2 43	− 5 43·74	− 6 6·0	10	15 38 49·02	123 13 9·3	7
26	6 38 47	+ 1 31·19	+ 2 8·1	5	...	...	8
26	6 38 47	+ 0 45·07	+ 2 7·4	5	...	...	9
27	6 55 21	− 1 18·97	+ 0 26·7	[illegible]	15 31 43·50	124 18 41·2	10
27	6 55 21	− 1 44·65	− 1 0·9	8	...	...	11
27	6 55 21	− 4 31·69	− 4 34·7	[illegible]	15 31 43·64	124 18 41·2	12
28	6 44 6	+ 0 55·40	− 11 12·1	10	...	...	13
29	6 29 52	+ 4 23·62	− 4 21·3	2	15 24 45·66	125 21 15·5	14
29	6 29 52	+ 0 7·32	+ 3 37·6	2	15 24 45·46	125 21 15·9	15
July 3	6 33 1	− 1 56·00	+ 7 13·8	[illegible]	..	...	16
3	6 33 1	− 4 21·39	+ 8 32·5	8	...	...	17
3	6 33 1	− 4 40·17	+ 3 17·4	8	15 11 2·37	127 19 42·1	18
[illegible]	7 7 29	+ 0 41·03	− 9 1·2	10	15 4 19·91	128 15 29·3	19
6	6 43 49	− 0 50·67	− 1 49·1	10	..	...	20
7	6 57 55	+ 7 44·47	+ 7 17·7	7	14 57 54·79	129 7 50·0	21
8	6 40 56	+ 2 39·51	+ 2 40·5	10	14 54 48·90	129 32 45·5	22
8	6 40 56	− 0 57·49	+ 1 39·5	10	...	...	23
10	6 36 51	+ 4 0·12	− 1 56·1	8	...	..	24
10	6 36 51	+ 3 12·89	− 1 58·5	8	14 48 42·64	130 21 30·5	25
11	6 45 37	− 2 54·45	+ 2 23·0	[illegible]	14 45 43·84	130 45 1·2	26
12	9 19 58	+ 1 0·95	− 2 0·1	[illegible]	14 42 29·77	131 10 35·9	27
13	9 9 32	− 1 55·60	+ 6 20·1	10	...	...	[illegible]
13	9 9 32	− 3 57·78	+ 7 2·9	[illegible]	14 39 40·78	131 32 48·5	29
14	9 31 38	+ 2 37·13	+ 8 10·5	10	14 36 51·87	131 54 58·7	30
15	9 16 19	− 1 28·59	− 5 30·9	10	14 34 11·01	132 15 59·1	[illegible]
18	9 36 26	+ 2 42·52	− 7 19·0	10	14 26 25·22	133 17 35·6	32
19	9 18 31	− 4 10·59	+ 1 40·0	10	...	...	33
20	8 46 7	+ 3 26·87	+ 4 34·3	8	14 21 41·91	133 55 48·5	34
21	8 46 16	+ 3 45·89	+ 2 45·4	6	14 19 23·50	134 14 39·2	35
21	8 46 16	− 5 52·98	− 7 0·2	6	14 19 23·30	134 14 39·9	36
22	9 0 35	+ 2 51·97	− 10 0·9	9	14 17 7·35	134 33 22·3	37
24	7 40 52	− 4 21·08	− 3 47·0	10	14 12 58·39	135 8 34·6	38

1898.	Windsor Mean Time.	Comet−Star. R.A.	Comet−Star. N.P.D.	No. of Comps.	Comet's Apparent R.A.	Comet's Apparent N.P.D.	Comp. star.
	h m s	m s	′ ″		h m s	° ′ ″	
July 26	9 5 36	− 4 4·53	+ 9 0·1	10	14 8 51·30	135 44 41·7	39
27	8 31 23	− 7 59·06	−10 37·5	4	...	...	40
27	8 31 23	− 9 31·49	−10 56·1	4	...	...	41
27	8 31 23	−11 21·94	− 2 54·3	4	14 7 0·36	136 1 31·2	42
28	9 1 9	+ 0 35·79	− 7 17·3	10	...	...	43
28	9 1 9	− 5 32·08	− 7 47·4	10	14 5 7·67	136 18 55·3	44
29	8 42 7	− 1 9·05	+ 9 21·7	10	...	...	45
31	8 38 27	− 0 30·11	+ 1 58·4	10	14 0 2·03	137 8 31·9	46
31	8 38 27	− 4 11·47	− 9 8·6	10	14 0 2·06	137 8 29·2	47
Aug. 1	9 10 59	− 5 48·71	+ 7 37·0	8	13 58 24·80	137 25 14·7	47
5	8 23 41	+ 3 0·04	+ 5 7·5	10	13 52 42·46	138 29 0·4	48
5	8 23 41	+ 1 19·63	− 2 40·5	10	13 52 42·43	138 29 0·6	49
6	8 16 38	+ 0 59·66	+ 7 33·7	1	...	...	50
8	7 34 41	+ 0 4·47	+ 4 41·3	10	...	...	51
9	8 31 39	+ 6 34·72	− 5 8·0	6	13 47 53·60	139 32 13·7	52
9	8 31 39	+ 4 12·27	− 6 36·7	6	...	...	53
11	7 44 58	− 6 57·67	+ 10 21·9	4	13 45 49·75	140 3 9·8	54
12	7 34 1	− 1 22·28	− 6 39·9	7	13 44 54·13	140 18 45·2	55
14	7 53 24	+ 2 51·47	− 5 18·0	10	13 43 6·05	140 50 24·4	56
17	7 52 59	+ 1 9·32	−10 15·6	10	13 40 47·95	141 37 51·4	57
19	7 37 24	− 0 10·21	+ 8 59·3	10	13 39 30·58	142 9 35·3	58
20	7 29 47	− 6 35·62	+ 6 52·5	10	13 38 55·68	142 25 34·1	59
20	7 29 47	− 6 37·63	+ 6 46·5	10	13 38 55·54	142 25 34·1	60
21	7 50 45	− 2 10·09	− 4 48·4	10	13 38 23·43	142 41 59·4	61
22	7 56 19	+ 4 26·29	+ 0 56·1	10	13 37 54·08	142 58 15·1	62
23	7 34 4	− 0 30·87	+ 0 54·4	10	...	...	63
26	7 47 26	+ 1 6·40	+ 1 2·2	10	13 36 21·48	144 4 0·5	64
Sept. 6	7 33 32	+ 3 5·40	+ 8 28·3	10	13 35 16·92	147 15 5·5	65
6	7 33 32	− 1 38·19	+10 10·5	10	13 35 16·62	147 15 6·8	66
7	7 59 8	+ 1 40·46	− 8 50·1	4	13 35 24·38	147 33 44·2	67
8	7 35 39	+ 4 5·39	− 2 12·5	8	13 35 33·39	147 51 50·0	68
8	7 35 39	− 3 21·06	+ 7 37·8	8	13 35 33·31	147 51 50·9	69
10	7 21 5	+ 0 43·28	+12 14·4	8	13 36 0·32	148 28 53·9	70
11	7 30 44	+ 1 50·19	+ 5 4·3	10	13 36 14·98	148 48 6·3	71
11	7 30 44	− 0 55·18	+ 4 22·0	10	13 36 14·91	148 48 3·9	72
12	7 25 57	− 5 14·34	+ 7 32·0	7	13 36 32·61	149 7 5·2	73
13	7 27 25	− 5 37·35	+ 1 10·3	7	...	...	74
15	7 32 30	− 4 37·16	− 9 33·1	8	13 37 39·23	150 5 28·6	75

1898.	Windsor Mean Time.	Comet—Star. R.A.	Comet—Star. N.P.D.	No. of Comps.	Comet's Apparent R.A.	Comet's Apparent N.P.D.	Comp. Star.
	h m s	m s	′ ″		h m s	° ′ ″	
Sept. 16	7 27 1	− 3 3·70	+ 7 0·8	10	13 38 6·71	150 25 20·3	76
16	7 27 1	− 4 9·47	+10 20·1	10	13 38 6·91	150 25 21·5	75
18	7 11 27	+ 3 22·15	− 8 21·5	6	13 39 5·86	151 5 21·8	77
18	7 11 27	+ 2 48·82	− 6 39·4	6	13 39 6·02	151 5 23·1	78
20	7 24 39	+ 1 0·83	−10 13·6	7	13 40 15·15	151 46 33·5	79
20	7 24 39	− 2 36·26	+ 0 8·7	7	13 40 14·86	151 46 33·4	80
23	7 26 24	− 3 1·86	− 1 45·7	10	13 42 16·51	152 49 40·7	81
30	7 25 41	− 2 31·28	+ 5 36·0	4	13 48 24·89	155 24 1·6	82
Oct. 3	7 26 46	+ 4 43·94	+ 9 7·0	3	13 51 42·93	156 33 19·9	83
3	7 26 46	+ 4 40·97	+ 9 25·0	3	13 51 43·11	156 33 21·6	84
5	7 32 51	+ 2 43·04	− 0 6·5	8	13 54 12·89	157 20 49·5	85
5	7 32 51	+ 2 23·98	− 0 32·3	8	13 54 12·77	157 20 49·8	86
6	7 47 32	− 4 6·96	+ 5 10·9	5	13 55 33·49	157 45 0·8	87
6	7 47 32	− 5 17·77	+ 5 26·0	5	13 55 33·74	157 45 1·9	88
9	7 32 36	+ 5 35·99	− 8 2·5	4	...	...	89
10	7 41 45	− 1 4·44	+ 8 32·5	10	14 1 34·77	159 23 0·7	90
15	7 45 20	+ 6 19·08	− 8 17·9	4	14 10 51·47	161 30 37·0	91
18	7 41 31	− 0 53·89	+ 5 43·7	10	14 17 42·63	162 49 32·3	92

Adopted Mean Places of the Comparison Stars for 1898·0.

Star.	Mean R.A.	Red. to App. R.A.	Mean N.P.D.	Red. to App. N.P.D.	Authorities.
	h m s	s	° ′ ″	″	
1	16 18 53·56	+4·26	117 25 48·4	+12·9	Arg.-Oeltzen 15599–600; Argent. Gen. Cat. 22232.
2	16 11 57·98	+4·25	117 47 21·7	+13·6	Arg.-Oeltzen 15482; Argent. Gen. Cat. 22077; Stone. 8858.
3	16 11 58·38	+4·27	118 21 33·4	+13·7	Arg.-Oeltzen 15481; Argent. Gen. Cat. 22078; Stone, 8857; Radcliffe, 1890, 4222.
4	15 49 48·58	+4·28	121 29 13·2	+16·5	Argent. Gen. Cat. 21576; Stone, 8653; Radcliffe, 1890. 4110.
5	15 43 16·84	+4·27	122 29 42·1	+17·4	Argent. Gen. Cat. 21432; Stone. 8594.
6	15 41 36·13	+4·28	123 10 46·2	+17·7	Argent. Gen. Cat. 21390.
7	15 44 28·45	+4·31	123 18 57·8	+17·5	Argent. Gen. Cat. 21454; Stone, 8602; Radcliffe, 1890, 4083.
8	15 33 42	+4·25	123 49	+18·6	Equatorial. Star = 10 mag.
9	15 34 28	+4·25	123 49	+18·5	Equatorial. Star = 10 mag.
10	15 32 58·21	+4·26	124 17 55·7	+18·8	Argent. Gen. Cat. 21198.

Star.	Mean R.A.	Red. to App. R.A.	Mean N.P.D.	Red. to App. N.P.D.	Authorities.
	h m s	s	° ′ ″	″	
11	15 33 24	+4·26	124 19	+18·8	Equatorial. Star = 9 mag.
12	15 36 11·05	+4·28	124 22 57·4	+18·5	Argent. Gen. Cat. 21274; Stone, 8533.
13	15 27 17	+4·24	125 1	+19·5	Equatorial. Star = 9 mag.
14	15 20 17·85	+4·19	125 25 16·6	+20·2	Argent. Gen. Cat. 20903; Stone, 8395.
15	15 24 33·92	+4·22	125 17 18·5	+19·8	Argent. Gen. Cat. 21003.
16	15 12 54	+4·16	127 12	+21·5	Equatorial. Star = 9 mag.
17	15 15 20	+4·18	127 11	+21·3	Equatorial. Star = 8½ mag.
18	15 15 38·35	+4·19	127 16 3·4	+21·3	Argent. Gen. Cat. 20803; Stone, 8351.
19	15 3 34·78	+4·10	128 24 7·9	+22·6	Argent. Gen. Cat. 20546; Stone, 8237.
20	15 1 55	+4·09	128 43	+22·9	Equatorial. Star = 8½ mag.
21	14 50 6·35	+3·97	129 0 8·5	+23·8	Argent. Gen. Cat. 20221; Stone, 8128.
22	14 52 5·40	+3·99	129 29 41·1	+23·9	Argent. Gen. Cat. 20274; Stone, 8150.
23	14 55 42	+4·03	129 31	+23·6	Equatorial. Star = 9 mag.
24	14 44 39	+3·92	130 23	+24·7	Equatorial. Star = 9 mag.
25	14 45 25·82	+3·93	130 23 4·4	+24·6	Argent. Gen. Cat. 20120.
26	14 48 34·33	+3·96	130 42 13·7	+24·5	,, ,, 20185.
27	14 41 24·94	+3·88	131 12 10·8	+25·2	,, ,, 20026.
28	14 41 32	+3·88	131 26	+25·2	Equatorial. Star = 9 mag.
29	14 43 34·66	+3·90	131 25 20·5	+25·1	Argent. Gen. Cat. 20081; Stone, 8067.
30	14 34 10·95	+3·79	131 46 22·4	+25·8	Argent. Gen. Cat. 19858.
31	14 35 35·79	+3·81	132 21 4·1	+25·9	Argent. Gen. Cat. 19889; Stone, 7993.
32	14 23 39·05	+3·65	133 24 27·8	+26·8	Argent. Gen. Cat. 19604; Stone, 7893.
33	14 28 8	+3·69	133 34	+26·7	Equatorial. Star = 8½ mag.
34	14 18 11·48	+3·56	133 50 47·0	+27·2	Argent. Gen. Cat. 19477; Stone, 7853.
35	14 15 34·10	+3·51	134 11 26·4	+27·4	Argent. Gen. Cat. 19418.
36	14 25 12·64	+3·64	134 21 13·0	+27·1	Argent. Gen. Cat. 19649; Stone, 7909.
37	14 14 11·89	+3·49	134 42 55·6	+27·6	Argent. Gen. Cat. 19379; Stone, 7819.
38	14 17 15·97	+3·50	135 11 54·0	+27·6	Argent. Gen. Cat. 19453.
39	14 12 52·42	+3·41	135 35 13·8	+27·8	Argent. Gen. Cat. 19354; Melb. 1870, 723; Stone, 7806; Cape Cat. 1885, 982.

Star.	Mean R.A.	Red. to App. R.A.	Mean N.P.D.	Red. to App. N.P.D.	Authorities.
	h m s	s	° ′ ″	″	
40	14 14 56	+3·43	136 12	+27·9	Equatorial. Star = 9 mag.
41	14 16 28	+3·46	136 12	+27·9	Equatorial. Star = 9 mag.
42	14 18 18·82	+3·48	136 3 57·8	+27·7	Argent. Gen. Cat. 19482; Stone, 7855.
43	14 4 29	+3·28	136 26	+28·3	Equatorial. Star = 7½ mag.
44	14 10 36·39	+3·36	136 26 14·6	+28·1	Argent. Gen. Cat. 19318.
45	14 4 26	+3·26	136 26	+28·2	Equatorial. Double star = 8½ and 9 mag. Preceding and south component employed.
46	14 0 28·97	+3·17	137 6 5·1	+28·4	Argent. Gen. Cat. 19120; Stone, 7713.
47	14 4 10·30	+3·23	137 17 9·4	+28·4	Argent. Gen. Cat. 19198.
47	14 4 10·30	+3·21	137 17 9·4	+28·3	" " 19198.
48	13 49 39·49	+2·93	138 23 24·2	+28·7	Argent. Gen. Cat. 18907; Stone, 7631.
49	13 51 19·84	+2·96	138 31 12·4	+28·7	Argent. Gen. Cat. 18945; Stone, 7650.
50	13 50 21	+2·92	138 36	+28·6	Equatorial. Star = 8½ mag.
51	13 48 55	+2·86	139 11	+28·6	Equatorial. Star = 9½ mag.
52	13 41 16·15	+2·73	139 36 53·0	+28·7	Argent. Gen. Cat. 18721; Stone, 7545.
53	13 43 39	+2·77	139 38	+28·7	Equatorial. Star = 8½ mag.
54	13 52 44·56	+2·86	139 52 19·4	+28·5	Argent. Gen. Cat. 18973; Stone, 7665.
55	13 46 13·67	+2·74	140 24 56·5	+28·6	Argent. Gen. Cat. 18837; Stone, 7589.
56	13 40 11·97	+2·61	140 55 13·9	+28·5	Argent. Gen. Cat. 18700; Stone, 7538.
57	13 39 36·10	+2·53	141 47 38·7	+28·3	Argent. Gen. Cat. 18686.
58	13 39 38·30	+2·49	142 0 7·9	+28·1	" " 18689.
59	13 45 28·75	+2·55	142 18 13·5	+28·1	Argent. Gen. Cat. 18814; Stone, 7578.
60	13 45 30·62	+2·55	142 18 19·5	28·1	Argent. Gen. Cat. 18817; Stone, 7579.
61	13 40 31·07	+2·45	142 46 19·8	+28·0	Argent. Gen. Cat. 18766; Stone, 7539.
62	13 33 25·47	+2·32	142 56 51·2	+27·8	Melb. Cat. 1870, 683; Argent. Gen. Cat. 18559; Stone, 7478; Cape Cat. 1885, 935.
63	13 37 57	+2·37	143 13	+27·8	Equatorial. Star = 8½ mag.
64	13 35 12·82	+2·26	144 2 30·8	+27·5	Argent. Gen. Cat. 18587; Stone, 7491.
65	13 32 9·59	+1·93	147 6 11·2	+26·0	Argent. Gen. Cat. 18532; Stone, 7468.
66	13 36 52·80	+2·01	147 4 30·1	+26·2	Argent. Gen. Cat. 18622; Stone, 7513
67	13 33 41·99	+1·93	147 24 28·1	+26·0	Argent. Gen. Cat. 18564.

Star.	Mean R.A.	Red. to App. R.A.	Mean N.P.D.	Red. to App. N.P.D.	Authorities.
	h m s	s	° ′ ″	″	
68	13 31 26·13	+1·87	147 53 36·7	+25·8	Argent. Gen. Cat. 18513; Stone, 7457.
69	13 38 52·38	+1·99	147 43 47·1	+26·0	Argent. Gen. Cat. 18663; Stone, 7527.
70	13 35 15·16	+1·88	148 16 13·9	+25·6	Argent. Gen. Cat. 18586; Stone, 7492.
71	13 34 22·95	+1·84	148 42 36·6	+25·4	Argent. Gen. Cat. 18572.
72	13 37 8·21	+1·88	148 43 16·4	+25·5	Argent. Gen. Cat. 18626; Stone, 7516.
73	13 41 45·02	+1·93	148 59 7·7	+25·5	Argent. Gen. Cat. 18727; Stone, 7547.
74	13 42 34	+1·91	149 25	+25·4	Equatorial. Star = 8½ mag.
75	13 42 14·55	+1·84	150 14 36·6	+25·1	Argent. Gen. Cat. 18738; Stone, 7550.
75	13 42 14·55	+1·83	150 14 36·6	+24·8	Argent. Gen. Cat. 18738; Stone, 7550.
76	13 41 8·60	+1·81	150 17 54·7	+24·8	Argent. Gen. Cat. 18715.
77	13 35 42·06	+1·65	151 13 18·9	+24·4	Argent. Gen. Cat. 18596; Stone, 7498.
78	13 36 15·54	+1·66	151 11 38·2	+24·3	Argent. Gen. Cat. 18611; Stone, 7504.
79	13 39 12·67	+1·65	151 56 23·0	+24·1	Argent. Gen. Cat. 18668; Stone, 7528.
80	13 42 49·40	+1·72	151 46 0·5	+24·2	Argent. Gen. Cat. 18755; Stone, 7554.
81	13 45 16·70	+1·67	152 51 2·6	+23·8	Argent. Gen. Cat. 18803; Stone, 7574.
82	13 50 54·61	+1·56	155 18 2·9	+22·7	Argent. Gen. Cat. 18931; Stone, 7643.
83	13 46 57·59	+1·40	156 23 51·0	+21·9	Argent. Gen. Cat. 18845; Stone, 7595.
84	13 47 0·74	+1·40	156 23 34·7	+21·9	Argent. Gen. Cat. 18846.
85	13 51 28·45	+1·40	157 20 34·3	+21·7	Argent. Gen. Cat. 18939; Stone, 7647.
86	13 51 47·38	+1·41	157 21 0·4	+21·7	Argent. Gen. Cat. 18950; Stone, 7651.
87	13 59 38·93	+1·52	157 39 28·1	+21·8	Argent. Gen. Cat. 19094.
88	14 0 49·97	+1·54	157 39 14·1	+21·8	„ „ 19121.
89	13 54 18	+1·30	159 6	+21·0	Equatorial. Star = 9 mag.
90	14 2 37·77	+1·44	159 14 7·1	+21·1	Melb. Cat. 1870, 713; Argent. Gen. Cat. 19164; Stone, 7733.
91	14 4 31·13	+1·26	161 38 34·8	+20·1	Gilliss's Cat. 1850, 9875.
92	14 18 35·08	+1·44	162 43 28·7	+19·9	„ „ 10059.

Observatory, Peninsula, Windsor,
N.S. Wales: 1898 Oct. 29.

Cometary Observations at the Liverpool Observatory, 1897–8. By W. E. Plummer, M.A.

The following observations form a continuation of the series of measures published in May 1896. The remarks made in that place concerning the instrument employed and the nature of the micrometers apply equally well to these observations. The general faintness of the Comets that have been recently discovered has operated unfavourably in many cases, and, notwithstanding the number of these objects recently discovered, the number of observations is less than in former years.

Comet VII. 1896 (*Perrine, December* 8).

Greenwich Mean Time of Observation.		☾ − ✱ R.A.	No. of Comparisons.	Apparent R.A. of ☾.	☾ − ✱ Declination.	No. of Comparisons.	Apparent Declination of ☾.	Log. Factor of Parallax in (a).	in (δ).	Star of Comparison.
1896.	h m s	m s		h m s	′ ″		° ′ ″			
Dec. 11	7 10 30·1	−2 21·99	25	1 9 53·22	+ 2 30·9	5	+ 5 23 10·2	−8·8616	−0·8143	1
22	7 0 55·0	+0 53·61	30	2 23 35·87	+ 5 8·2	6	+ 1 35 11·6	−9·1169	−0·8386	2
27	6 17 40·6	−2 18·55	25	2 52 42·27	− 5 52·5	5	+ 0 28 3·8	−9·3045	−0·8450	3
27	6 17 40·6	−2 3·88	25	2 52 42·31	− 0 56·7	5	+ 0 28 2·6	−9·3045	−0·8450	4
28	8 0 23·2	−1 24·28	Ret.	2 58 34·21	−10 49·8	Ret.	+ 0 16 29·2	−8·7774	−0·8457	5
30	8 40 7·3	+1 9·87	„	3 9 16·30	+10 15·3	„	− 0 2 19·7	−7·7051	−0·8474	6
1897. Jan. 5	7 42 37·9	−1 41·53	25	3 38 0·62	− 0 47·4	5	− 0 37 56·5	−8·9920	−0·8506	7
8	8 2 0·4	−3 6·97	30	3 51 4·70	− 4 17·4	6	− 0 46 8·3	−8·8522	−0·8514	8
20	7 3 51·2	−0 58·25	Ret.	4 35 8·92	+ 3 11·8	Ret.	− 0 32 20·7	−9·1785	−0·8499	9
26	9 32 45·0	−1 30·65	„	4 53 56·86	+ 5 3·4	„	− 0 6 38·5	+8·8988	−0·8478	10
26	9 32 45·0	+0 35·01	„	4 53 56·73	− 5 9·1	„	− 0 6 41·2	+8·8988	−0·8478	11

Periodic Comet of D'Arrest.

Greenwich Mean Time of Observation.	☄ − ✳ R.A.	No. of Comparisons.	Apparent R.A. of ☄.	☄ − ✳ Declination.	No. of Comparisons.	Apparent Declination of ☄.	Log. Factor of Parallax in (α).	Log. Factor of Parallax in (δ).	Star of Comparison.
1896. d h m s	m s		h m s	′ ″		° ′ ″			
July 9 14 42 6·0	+0 52·08	Ret.	2 31 19·92	+9 56·1	Ret.	+ 6 33 50·8	−9·5261	−0·8327	12
Comet III. 1897 (Perrine, October 16).									
Oct. 20 8 40 46·3	+1 44·69	25	3 9 22·60	−5 31·5	5	+72 19 32·0	−0·0371	+9·6795	13
22 9 27 32·6	+ 2·08	30	2 45 11·64	+1 25·7	6	+75 15 36·8	−0·0294	+0·0513	14
22 9 27 32·6	− 15·18	30	2 45 11·21	+1 23·4	6	+75 15 40·2	−0·0294	+0·0513	15
24 7 55 36·0	+0 59·14	25	2 11 38·29	+0 30·1	5	+77 47 35·8	−0·1720	+9·9922	16
26 8 23 1·9	+2 4·67	Ret.	1 20 17·82	+0 31·0	Ret.	+79 58 2·3	−0·1286	+9·4885	17
29 8 58 27·0	−0 26·2	”	23 26 37·0	−1 31·8	”	+81 39 47·3	−8·8494	+0·6212	18
29 8 58 27·0	−0 40·0	”	23 26 35·3	−2 9·9	”	+81 39 45·1	−8·8494	+0·6212	19
30 10 13 27·3	+4 14·6	”	22 41 29·6	+7 31·9	”	+81 39 36·2	+0·0390	+0·5586	20
30 10 13 27·3	−4 20·2	”	22 41 31·3	−3 47·8	”	+81 39 33·9	+0·0390	+0·5586	21
Nov. 1 10 6 13	+8 51·2	”	21 26 25·2	+3 12·7	”	+80 51 42·6	+0·2174	+0·3685	22
Comet I. 1898 (Perrine, March 19).									
1898. Mar. 21 16 4 11·0	+2 2·02	25	21 24 35·02	−1 52·4	5	+18 25 24·1	−9·5648	−0·8126	23
21 16 4 11·0	+ 13·41	25	21 24 35·20	+4 5·6	5	+18 25 27·2	−9·5648	−0·8126	24
22 16 9 20·5	−1 45·03	25	21 28 18·26	−0 59·7	5	+19 27 52·5	−9·5663	−0·8056	25
23 16 20 30·2	+2 37·63	12	21 32 5·82	+2 10·1	3	+20 30 28·7	−9·4656	−0·7956	26

1896.	Greenwich Mean Time of Observation. h m s	☄ – ✱ R.A. m s	No. of Comparisons.	Apparent R.A. of ☄. h m s	☄ – ✱ Declination. ′ ″	No. of Comparisons.	Apparent Declination of ☄. ° ′ ″	Log. Factor of Parallax in (α).	Log. Factor of Parallax in (δ).	Star of Comparison.
Mar. 27	15 56 23·9	+1 38·42	25	21 47 35·14	+4 5·5	5	+24 36 13·9	−9·5846	−0·7935	27
27	15 56 23·9	−0 24·10	25	21 47 35·07	+1 47·1	5	+24 36 14·4	−9·5846	−0·7935	28
28	15 32 6·4	−2 20·81	Ret.	21 51 31·83	+4 34·8	Ret.	+25 35 58·8	−9·5896	−0·8061	29
31	15 11 54·1	+2 52·80	30	22 3 50·38	+6 25·1	6	+28 34 25·2	−9·5984	−0·8105	30
31	15 11 34·1	+0 59·85	30	22 3 50·45	+6 38·3	6	+28 34 25·7	−9·5984	−0·8105	31
Apr. 1	15 27 38·0	+1 59·63	Ret.	22 8 3·41	+4 25·4	Ret.	+29 32 50·2	−9·6048	−0·7952	32
3	15 40 5·4	+2 47·08	25	22 16 46·36	−1 4·1	5	+31 29 4·3	−9·6140	−0·7773	33
6	14 53 31·3	−1 25·33	30	22 29 59·42	+8 22·2	6	+34 13 43·7	−9·6181	−0·8076	34
8	14 59 5·0	+4 52·25	25	22 39 11·18	−7 36·9	5	+36 0 21·7	−9·6292	−0·7970	36
8	14 59 5·0	−5 49·00	25	22 39 11·16	+1 2·3	5	+36 0 20·8	−9·6292	−0·7970	36
12	15 30 16·2	+0 17·56	Ret.	22 58 18·90	+1 8·6	Ret.	+39 21 42·5	−9·6557	−0·7524	37
14	13 32 45·4	+1 59·79	25	23 7 43·51	+5 17·7	5	+40 51 30·9	−9·6428	−0·8073	38
14	13 32 45·4	−0 41·08	25	23 7 43·32	−4 7·5	5	+40 51 31·3	−9·6428	−0·8073	39
25	12 50 11·3	−0 43·56	Ret.	0 4 41·12	−5 18·6	Ret.	+47 58 21·7	−9·5475	−0·8805	40
30	13 50 29·0	−3 11·33	,,	0 32 2·50	−1 16·7	,,	+50 24 19·8	−9·6567	−0·8311	41
May 2	13 49 16·6	−4 1·49	,,	0 42 57·51	−2 31·6	,,	+51 13 44·1	−9·6588	−0·8316	42
				Comet V. 1898 (Perrine, June 14).						
June 17	12 58 32·2	+7 15·75	Ret.	3 44 54·86	+2 45·9	Ret.	+58 2 25·7	−9·6434	−0·8487	43

Comet VII. 1898 (Perrine-Chofardet, September 14).

Greenwich Mean Time of Observation.		✱ − ⋆ R.A.	No. of Comparisons.	Apparent R.A. of ✱.	✱ − ⋆ Declination.	No. of Comparisons.	Apparent Declination of ✱.	Log. Factor of Parallax in (α).	Log. Factor of Parallax in (δ).	Star of Comparison.
1896.	h m s	m s		h m s	′ ″		° ′ ″			
Sept. 16	15 30 40·0	−1 58·92	25	9 57 55·60	+0 43·6	5	+29 8 30·2	−9·5908	−0·8296	44
21	16 25 11·3	+2 0·61	20	10 29 41·77	+9 1·0	4	+25 47 48·5	−9·5898	−0·8101	45
25	16 16 25·4	+0 43·10	Ret.	10 55 19·60	+0 49·4	Ret.	+22 34 59·4	−9·5754	−0·8305	46

Notes.

Comet VII. 1896 December 11.—Comet easily seen, notwithstanding moonlight. Bright wire illumination defective. December 22.—Slight fog and haze; observations unsatisfactory. December 28.—The instrument was not reversed; parallel doubtful. January 20.—Comet brighter than expected, but the individual measures are discordant. January 26.—Sky not very transparent; Comet too faint an object for accurate observation in this instrument.

Periodic Comet of D'Arrest.—The approaching daylight rendered this observation very difficult. The observation is not considered trustworthy.

Comet III. 1897 October 20.—Owing to the position of the Comet, the telescope could not be conveniently reversed. Error of adjustment of the parallel will probably affect the observations. October 24.—The Comet better seen than on the previous night. October 29.—No suspicion of nucleus; the observation refers to the centre of the nebulosity. November 1.—The Comet very feeble; some of the measures have been rejected as evidently erroneous.

Comet I. 1898 March 21.—Comet fairly bright; distinct nucleus of about 8th mag., and suspicion of tail. March 23.—Haze and fog; Comet seen with difficulty, and observation of little value. March 31. Coma estimated at 3′ diameter and tail about 20′ in length. April 1.—The observation was unsatisfactory; Comet seemed so ill-defined. April 6.—Notwithstanding the strong moonlight the Comet was easily seen, and the observation thought good. April 14.—Apparently no condensation; the centre of the nebulosity observed. April 25.—Images very bad; clouds rising rendered later observation impossible. May 2.—Comet appears as a faint nebulosity 2′ in diameter; centre observed.

Comet VII. 1896, Perrine.

Date.	Star's Designation or Authority for Places.	Mean R.A. Equinox of Year. h m s	Correction to Mean R.A. s	Mean Declination. Equinox of Year. ° ′ ″	Correction to Mean Declination. ″	Letter of Reference.
1896. Dec. 11	A.G.Z. Albany, No. 353	1 12 11·08	+ 4·20	+ 5 20 12·1	+ 27·2	1
22	Glasgow, 1860, No. 551; Glasgow, 1890, No. 195	2 22 37·77	+ 4·49	+ 1 29 39·9	+ 23·5	2
27	Glasgow, 1860, No. 695; Glasgow, 1890, No. 245	2 54 56·22	+ 4·60	+ 0 33 35·0	+ 21·3	3
27	Harvard College, Zones Nos. 34, 35; No. 15	2 54 41·62	+ 4·60	+ 0 28 38·0	+ 21·3	4
28	Schjellerup, No. 869	2 59 53·87	+ 4·62	+ 0 26 58·1	+ 20·9	5
30	Göttingen, Nos. 863–4	3 8 1·80	+ 4·63	− 0 12 55·0	+ 20·0	6
1897. Jan. 5	Göttingen, No. 961; Paris, No. 4428	3 39 40·47	+ 1·68	− 0 37 14·8	+ 5·7	7
8	Schjellerup, No. 1240	3 54 9·97	+ 1·72	− 0 41 56·3	+ 5·4	8
20	Göttingen, No. 1282–3	4 36 5·32	+ 1·85	− 0 35 35·6	+ 3·1	9
26	Göttingen, No. 1414	4 55 25·65	+ 1·86	− 0 11 45·1	+ 3·2	10
26		4 53 19·86	+ 1·86	− 0 1 35·4	+ 3·3	11
	Periodic Comet of D'Arrest.					
July 9	Piazzi II., No. 123; Paris, No. 3205	2 30 25·80	+ 2·04	+ 6 23 38·4	+ 16·3	12
	Comet III., 1897.					
Oct. 20	Arg. Oeltz., No. 3539	3 7 28·04	+ 9·87	+ 72 24 48·2	+ 15·3	13
22	Arg. Oeltz., No. 3196; B. B. vi. No. 113	2 44 58·67	+ 10·89	+ 75 13 52·7	+ 18·4	14
22	Arg. Oeltz., No. 3199; B. B. vi. No. 114	2 45 15·52	+ 10·87	+ 75 13 58·5	+ 18·3	15
24	Groombridge, No. 469; Arg. Oeltz., No. 2520, 1	2 10 27·50	+ 11·65	+ 77 46 41·9	+ 22·8	16

Date.	Star's Designation or Authority for Places.	Mean R.A. Equinox of Year. h m s	Correction to Mean R.A. s	Mean Declination. Equinox of Year. ° ′ ″	Correction to Mean Declination. ″	Letter of Reference.
1896. Oct. 26	Quoted from *Monthly Notices*, 1897 November	1 18 1·85	+ 11·30	+ 79 57 2·6	+ 28·7	17
29	Carrington, No. 3613	23 26 57·3	+ 5·85	+ 81 40 42·9	+ 36·2	18
29	Carrington, No. 3616	23 27 9·8	+ 5·80	+ 81 41 19·0	+ 36·0	19
30	Carrington, No. 3472	22 37 12·92	+ 2·10	+ 81 31 27·8	+ 36·5	20
30	Carrington, No. 3495	22 45 48·87	+ 2·68	+ 81 42 45·1	+ 36·6	21
Nov. 1	Northfield Mer. Obsns., *Ast. Journal*, No. 421	21 17 38·10	− 4·08	+ 80 47 56·1	+ 33·8	22
		Comet I., 1898.				
1898. March 21	A.G.Z. Berlin A., No. 8751	21 22 32·58	+ 0·42	+ 18 27 22·6	− 6·6	23
21	A.G.Z. Berlin A., No. 8763	21 24 21·38	+ 0·41	+ 18 21 27·5	− 5·9	24
22	A.G.Z. Berlin A., No. 8802	21 30 2·88	+ 0·41	+ 19 28 58·1	− 5·9	25
23	A.G.Z. Berlin B., No. 8285	21 29 27·79	+ 0·40	+ 20 28 24·6	− 6·0	26
27	A.G.Z. Berlin B., No. 8427	21 45 56·36	+ 0·36	+ 24 32 13·8	− 5·4	27
27	A.G.Z. Berlin B., No. 8438	21 47 58·82	+ 0·35	+ 24 34 32·9	− 5·6	28
28	A.G.Z. Cambridge, No. 13058	21 53 52·31	+ 0·33	+ 25 31 29·4	− 5·4	29
31	A.G.Z. Cambridge, No. 13175	22 0 57·27	+ 0·31	+ 28 28 5·5	− 5·4	30
31	A.G.Z. Cambridge, No. 13204	22 2 50·29	+ 0·31	+ 28 27 52·7	− 5·3	31
April 1	A.G.Z. Cambridge, No. 13245	22 6 3·48	+ 0·30	+ 29 28 30·1	− 5·3	32
3	A.G.Z. Leiden, Nos. 7–8	22 13 59·09	+ 0·27	+ 31 30 13·5	− 5·1	33
6	A.G.Z. Leiden, Nos. 106–109	22 31 24·52	+ 0·23	+ 34 5 25·9	− 4·4	34

Date	Star's Designation or Authority for Places.	Mean R.A. Equinox of Year.	Correction to Mean R.A.	Mean Declination. Equinox of Year.	Correction to Mean Declination.	Letter of Reference.
1898.		h m s	s	° ′ ″	″	
April 8	A.G.Z. Lund, Nos. 66, 523	22 34 16·72	+ 0·21	+36 8 3·1	− 4·5	35
8	A.G.Z. Lund, Nos. 289, 329, 556	22 44 57·96	+ 0·20	+35 59 22·5	− 4·0	36
12	A.G.Z. Lund, Nos. 44, 47, 528	22 58 1·18	+ 0·16	+39 20 37·4	− 3·5	37
14	A.G.Z. Berne, No. 17515	23 5 43·58	+ 0·14	+40 46 16·4	− 3·2	38
14	A.G.Z. Berne, No. 17554	23 8 24·27	+ 0·13	+40 55 41·8	− 3·0	39
25	A.G.Z. Berne, No. 71	0 5 24·90	+ 0·08	+48 3 41·0	− 0·7	40
30	A.G.Z. Cambridge, No. 285	0 35 13·72	+ 0·11	+50 25 36·0	+ 0·5	41
May 2	A.G.Z. Cambridge, No. 379	0 46 58·84	+ 0·16	+51 16 14·9	+ 0·8	42
		Comet V., 1898.				
June 17	A.G.Z. Helsingfors, No. 3174	3 37 37·68	+ 1·43	+57 59 38·2	+ 1·6	43
		Comet Perrine-Chofardet.				
Sept. 16	A.G.Z. Cambridge, No. 5205	9 59 52·14	+ 2·38	+29 7 59·9	−13·3	44
21	A.G.Z. Cambridge, No. 5398	10 27 38·86	+ 2·30	+25 39 1·6	−14·1	45
25	A.G.Z. Berlin B., No. 4152	10 54 34·27	+ 2·23	+22 34 24·6	−14·6	46

Liverpool Observatory:
1898 *December* 8.

Observations of the Leonids, 1898 November.

(*Communicated by Dr. G. Johnstone Stoney.*)

Extracts from letters written by Professor E. E. Barnard and Mr. J. W. Meares to Dr. Stoney.

Professor Barnard to Dr. Stoney.

"For some days preceding this date [November 14, astronomical time] the sky had been densely clouded all night (and day also). I began a watch on the night of the 11th, and continued this through without stopping until the 16th, and also in the latter hours of the 17th. These watches I kept up from 5 or 6 P.M. till 6 and 7 A.M. of each date, in hopes of getting even a moment's glimpse of the sky.

"The sky suddenly cleared shortly after midnight on the 14th. I soon saw there were a few meteors, but not noticeable, which could be traced back to the radiant, though they were mostly low in the N.W. near *α Cygni.* They became more frequent, and some large ones were seen. From this till daylight several hundreds were seen—many of the 1st magnitude, and a few brighter. Very few were seen near the radiant and none at it.

"They left bluish green streaks which persisted for a moment. There were no actual explosions; they simply increased rapidly in their light as if ploughing through a great resistance which rapidly consumed them. Their flight was very rapid, and their average position of appearance from the radiant would be 90° or much more. This would account for their great rapidity. Many appeared far west of *Orion* and quite a number in *Ursa Major.*

"As dawn began to show feebly they had markedly ceased, and before daylight had advanced enough to make much effect on the stars the meteors seemed to have ceased altogether. It seemed to me the maximum was reached between 3 and 4 A.M., perhaps nearer 4. It was the finest display of meteors I have yet seen.

"I had five cameras pointed to different parts of the sky, but from knowing their location no very bright meteors were seen to cross their fields. I have developed some of the plates, the least promising—those made at the tail-end of the display—but so far no trails.

"During frequent watches of the entire night of the 16th not a single *Leonid* was seen—the radiant seemed perfectly dead. The watch in the latter part of the night of the 17th gave the same result.

"I am inclined to think that the entire display was visible here on the morning of the 15th [civil time], and it had just begun when the sky cleared, and ceased before daylight. However, this point will be settled by observations elsewhere.

"We have a few counts here that may settle the maximum."

In a subsequent letter dated 1898 November 26 Professor Barnard refers to a telegram he had received from Dr. Stoney, calling his attention to November $15^d\ 17^h$ G.M.T., as being the time when the earth would reach the node of the instantaneous ellipse which on that date osculates the orbit of the part of the stream through which the earth passed in 1866, if we assume the correctness of Adams's elements, and take account of the perturbations which have affected the orbit since 1866. Referring to this, Professor Barnard writes :—

"This would place the event November $15^d\ 17^h$ G.M.T. On that night the radiant was dead; no meteors were seen that could in any way be assigned to it. The maximum as observed here would appear to have been not far from November 14^d 21^h–22^h G.M.T."

Yerkes Observatory, Williams' Bay, Wisconsin :
1898 *November* 20.

Mr. J. W. Meares to Dr. Stoney.

"I kept a watch for the *Leonid* meteors here on the 13th and 14th instant.

"On the 13th I only watched from 12^h–13^h. There was a heavy mist low down, and no stars could be seen lower than 15° from the horizon. No meteors at all were seen. On the 14th it was quite clear, and I watched from 12^h–14^h. There were exceptionally few meteors seen, and of these only 4 appeared to have been *Leonids.* I have made no attempt at determining the radiants, as I am inexperienced in this work. A list of the meteors is given below.

"*Writers' Buildings, Public Works Department, Calcutta :*
1898 *November* 16.

"Calcutta Local Time. 1898 Nov. 14. h	m	Mag.	
12	5	−1	White, lasting trail, quick, from Taurus eastward.
12	30	−1	Yellow, trail momentary, quick, *Leonid* (1).
12	33	4	Yellowish, no trail, very quick.
12	53	4	,, ,, ,,
12	56	faint	,, ,, ,,
13	0	1	Yellow, bright trail, quick, *Leonid* (2).
13	6	faint	Yellowish, no trail, very quick.
13	15	,,	,, ,, quick.
13	15½	1	Yellow, bright trail, quick, *Leonid* (3).
13	23	1	,, ,, ,, *Leonid* (4).
13	28	faint	Yellowish, no trail, very quick.
13	35	−1	Orange, short trail, very quick.
13	43	faint	Yellowish, no train.

"Up to 14^h no more meteors.

"Calcutta local time, $5^h\ 53^m$ east of Greenwich."

It appears from these letters that the observations in India were made from twelve to ten hours before the beginning of the shower which visited America; and accordingly that the *Leonids* observed in India were a few *clino-Leonids*, the sparse shower of which lasts several days. On the other hand, the much denser display which was seen in America was fortunately observed from its commencement till its close. It was thus ascertained that it lasted only a moderate number of hours; from which we may infer that the Earth has this year passed through the extreme front of the main stream, which consists of *ortho-Leonids*, and the denser parts of which produce the imposing spectacle in the Earth's atmosphere of Great November Showers.

Observations of Meteors made at the Royal Observatory, Cape of Good Hope, on 1898 *November* 13 *and* 14. By David Gill, C.B., F.R.S., &c., Her Majesty's Astronomer.

Besides provision for eye observations, five cameras were exposed from midnight till daylight on November 13 and 14. These were arranged so as to cover an area of the sky limited by two circles of about 20° and 50° in radius, having their common centre in the radiant (R.A. 10^h, Decl. $+22°$). A Cooke doublet of 5 inches aperture and 19 inches focus was directed to the radiant as soon as it had risen sufficiently above the horizon. All these cameras were attached to equatorials driven by clockwork and carefully guided throughout the exposure. The plates were exchanged every hour.

Besides an observer, whose duty it was to attend to the guiding of each telescope, another observer was on the watch with each telescope to record the time and position of every meteor that crossed the field covered by each particular camera. The sky was perfectly clear, but no meteors of remarkable brilliancy crossed the fields of the cameras, and those approaching the brightness of 1st magnitude stars moved so swiftly as not to impress any visible record on the plate.

The meteors in the area of Pickering's charts of the radiant were specially observed by Mr. J. Power. Mr. Innes observed the sky towards the south-east, and Mr. W. de Sitter more particularly to the north-east.

Messrs. Power and de Sitter were chiefly on the outlook for meteors radiating from *Leo*, but they also noted a good many radiating from *Orion*. Mr. Innes endeavoured to note all the meteors visible in the area watched by him.

Meteors observed at the Royal Observatory, Cape of Good Hope, on 1898 Nov. 13–14.

Greenwich Mean Time 1898 Nov. 13. h m s	Mag.	Colour.	Path From. R.A. °	Decl. °	To. R.A. °	Decl. °	Notes.	Observers.
12 3 45	1	...	95	+37½	62	+38	... ...	D. S.
12 13 34	3	Y	146½	+ 9	142½	+20		J. P. and D. S.
...	...	...	...		...		... ...	„
12 22 34	1	BW	151	+ 7	149	+13	... ...	„
13 12 59	...	...	87½	−29	67	−16	... ...	„
13 29 9	3	Y	148 148	+20 +16	152½	+17	First half of path not seen by D. S.	„
14 2 54	4	„	152	+23	152	+29	... ...	„
14 6 0	3	„	147½	+25	149	+30	... ...	J. P.
14 6 4	1	„	153½	−12½	167	−27	... ...	D. S.
Nov. 14.								
12 39 56	0	Ruddy	101	+24	96	+35	Green train	J. P. and D. S.
13 2 54	0	W	83	+ 1	70	+ 2	Disappeared behind house. Streak	„
13 5 45	3½	Y	147	+23½	149	+28		„
13 14 13	−2	YW	150	+22½	147½	+23½	Very bright train	D. S.
13 22 49	0	...	117½	+ 7½	100	+15	... ...	J. P.
13 23 56	−2	BW	139	+23	114	+33	Long green train, 4 secs. duration	J. P. and D. S.
13 28 56	−3	„	111	+34½	87	+38	Green train. Disappeared behind house	„
13 29 26	0	...	100	−2	107	+35	... ...	„
13 31 58	4	...	152½	+24	155	+26	... ...	„
13 40 30	3⅔	...	152⅔	+24	155	+26	... ...	„
13 43 46	2	BW	149	+ 8½	152	+17½	Train. Slow	„
13 49 17	2½	„	151½	+19½	156	+13	Slow	„
13 53 57	−2	„	148	+20½	132½	+22	Green train. Slow	„
13 58 15	2	W	160	+22	168	+20	Short train.	„
14 16 28	−1½	...	152⅔	+19	162	+17	Green train. Very slow	„
14 20 2	2	...	114	+32½	94	+37	Green train	„
14 23 19	2½	...	144	+22	136	+23	Streak	„
14 29 36	−1½	...	151½	+16	163	+ 6	Green train. Slow	„

Observers { J. P. = John Power.
D.S. = W. de Sitter.
I. = R. T. A. Innes.

G.M.T. 1898 Nov. 13. h m	Mag.	Path From.	Path To.	Notes.	Observer.
12 10	...		...	Commenced watch. No cloud	I.
12 15	3		...	Two, short paths, swift, both towards west	„
12 20	3		...	In S.W. Got brighter—swift	„
12 25	1		...	Not a Leonid	„
12 30	3		...	Swift, across zenith { Both from, say, Aries to Canopus, but only 10° in length	„
12 41	1		...	Not a Leonid (The Leonids are about 15° to 20° in length.)	
12 50	2	160°−64°	179°−78°	θ Argûs to ε Chameleontis, 8°, swift. The lengths of the paths are from estimates made at time of observation	„
12 54	3		...	Not a Leonid. Near α Eridani, due N. to S.	„
13 1	4	178−76	195−75	Very short. κ Chameleontis to $13^h\ 0^m - 75°$. Not a Leonid	„
13 5	3		...	Very short, not a Leonid. N. to S. near β Hydræ	„
13 15	3		...	„ „ Near α Circini	„
13 16	3		...	„ „ Near α Leonis. Direction Procyon to α Leonis	„
13 21	2		...	Fine trail 5°, near α Leonis, Leonid, no head or star seen	„
13 28	4		...	Leonid, through Canopus, short, swift	„
13 34	...		...	Near Antlia, W. to E., slowish, sporadic	„
13 40	2	167−58	173−63	Leonid, 5°, x Carinæ to λ Centauri, 20° due N. to S. between Magellanic Clouds, not very swift (Orionid or Taurid)	„ „
13 43	1	181−50	195−60	Leonid, δ Centauri to $13^h\ 0^m - 60°$, swift	„
13 49	2		...	In zenith, N. to S. 10°	„
13 59	4				
14 6	3		...	20°, midway between α Leonis and β Crucis. Leonid	„
14 9	2	118−53	97−70	Streak left, χ Argûs to π Doradûs, Leonid	„
14 17	4		...	10°, in Antlia, direction from α Orionis	„
14 33	...		...	Watch discontinued, too much daylight	„
Nov. 14.					
7 20	...		...	Started, no cloud } No meteors.	
7 37	...		...	Ended „ }	„
10 25	...		...	Resumed, some cloud in south	„
10 32	♃	160−66	172−63	Splendid meteor with train, L Carinæ to λ Centauri, slow, Orionid?	„
10 37	4	129−53	142−53	Slow, o Argûs to between L Velorum and κ Argûs (Orionid?)	„
10 44	3		...	Direction, Sirius towards ζ Argûs, nearer latter, slow, Orionid	„
10 50	1		...	Very short, near Apus, slow, Orionid	„

G.M.T. 1898 Nov. 13. h	m	Mag.	Path From	To.	Notes.	Observer.
10	53	1	...		Very short, 1° in Reticulum, direction Achernar to Canopus, sporadic	I. "
10	54	1	...		Slow, direction θ Orionis to Sirius, but the path was *much further south*, in Antlia. Two others seen simultaneously (all Orionids)	" "
11	0	3	125°−53°	129°−59°	1°, near ε Argûs towards *d* Velorum (Orionid)	"
11	3	4	...		In Chameleon. Direction from Orion	"
11	4	3	...		In Antlia, direction from Canopus, 3°. Sporadic	"
11	20	3	...		In Volans, 5°, Leonid	"
11	42	3	93−55	112−79	5°, Very swift, δ Pictoris to ε Mensæ. Leonid	"
11	54	1	...		Slow, 15°, in Antlia, direction from Orion	"
12	6	...	...		Gave up.	

The November Meteors, 1898.

(*Communicated by the Astronomer Royal for Scotland.*)

Except in the early part of the night of the 13th, the weather was very unfavourable for the observation of the November meteors on the dates of the two principal showers. Watch was kept for the *Leonids* on the 13th, 14th, and 15th, with the results tabulated below. The observers were R. Copeland, T. Heath, and A. J. Ramsay.

On the 24th watch was kept for the *Bielids* from dusk until past midnight, but the sky was overcast all the time and rain fell at intervals. Although the moon was occasionally seen dimly through misty clouds, no stars were at any time visible. Professor Tacchini has kindly informed me that the sky was fairly clear at Rome from 5^h to 7^h, and especially so towards the east, but that there was an entire absence of the *Andromeda* meteors. At all the other stations from which I have heard, the sky was overcast.

Date. 1898.	Observer.	Duration of Watch.	From–To.	Result.
Nov. 13	R. C.	$2^h\ 11^m$	$11^h\ 17^m$ to $13^h\ 28^m$	One Leonid at $12^h\ 36^m\ 56^s$ ± G.M.T. from direction of the radiant across α Canum Ven. Nine other meteors, within 30° of the head of Leo, of which only three appeared to come from the radiant.
	T. H.	$1^h\ 30^m$	11^h to 12^h and $13^h\ 30^m$ to 14^h	One Leonid at $13^h\ 33^m\ 36^s$ ± G.M.T. from 149° + 25° to 152° + 36°, mag. 2, colour blue. Three smaller meteors with short paths in neighbourhood of Leo.
	A. J. R.	$1^h\ 33^m$	At intervals between $11^h\ 35^m$ and $13^h\ 50^m$	One Leonid and five other meteors directed *towards* the constellation Leo.

Date.	Observer.	Duration of Watch.	From—To.	Result.
1898.				
Nov. 14	A. J. R.	$4^h\ 15^m$	$10^h\ 45^m$ to 15^h	No meteors seen. Very cloudy up t $12^h\ 15^m$, and then completely overcas Slight rain at 13^h.
	T. H.	2^h	11^h to 13^h	No meteors seen. Sky cloudy.
	R. C.	44^m	17^h to $17^h\ 44^m$	Sky clear overhead, although cloudy u to altitude of 20°. Three well-marke Leonids (1 – 2 mag.), starting 20° fro radiant, of which two moving towar tail of Ursa Major and one towar Orion. Another meteor (1 mag.) fro end of tail of Ursa Major towards Le
Nov. 15	A. J. R.	$5^h\ 35^m$	$11^h\ 25^m$ to 17^h	No meteors. Sky cloudy all night.

On the 13th R.C. also saw two large bolide-like meteors fall to the south from a point overhead, and a resident on Blackford Hill saw five large meteors fall into the constellation *Cetus* from a direction S.E. of the zenith. Most of these could be referred to a radiant near *Pollux.*

The Rev. A. Mackay, Westerdale Manse, Halkirk, Caithness, has written to me that on November 14 in clear intervals between $11^h\ 16^m$ and $13^h\ 23^m$ he saw fourteen meteors in all, of which eleven were possible *Leonids.*

A whole-plate camera equatorially mounted and provided with a driving clock was kept in readiness each night, under the care of A. J. R.; but no plates were exposed owing to the scarcity of meteors.

Observations of the Leonids, 1898 *November, made at the Cambridge Observatory.* By Arthur R. Hinks, B.A.

(*Communicated by Sir Robert Ball.*)

In my attempt to observe the *Leonids* this year I was fortunate in having the help of the members of the class to which I have had the pleasure of teaching practical astronomy this term. To Messrs. R. C. Maclaurin, Fellow of St. John's College; L. N. G. Filon, advanced student, King's College; H. E. Wimperis, advanced student, Caius College; R. Casson, A. B. Field, J. H. Field, and M. Walker, undergraduates of St. John's College, my thanks are due for their energetic help under very depressing circumstances.

Our programme was to watch from $11^h{\cdot}0$ until dawn on November 13, 14, 15, and to attempt three things: a continuous count of the number of meteors visible per five minutes; a record of as many paths as possible from visual observations; and a

photographic record of paths within 5° of the radiant, with a 5-inch portrait lens mounted on the Northumberland Equatorial.

The nights of 1898 November 13 and 15 were entirely cloudy, and nothing whatever was seen.

The night of 1898 November 14 was slightly more favourable. The clouds were almost continuous, but very thin in places, with an occasional break almost clear. Photography was quite out of the question. There were not enough stars visible to allow us to record any paths visually. But during a continuous watch by two or more observers from 11^h to 18^h we counted altogether thirty-six meteors, of which perhaps thirty-two were *Leonids*.

A list of the meteors seen, with extracts from our notes, is given below. We have marked with an L all those which, so far as we could judge through the clouds, were *Leonids*. The recorded magnitudes are of scarcely any value, owing to the continually varying thickness of the cloud.

G.M.T.			Magnitude.	Streak.	
13	54	L	V. bright	Green phosphorescent	Lit up the clouds
14	10	Not a Leonid			
14	15	L	1	Gr. phosph.	

From $14^h\ 0^m$ to $14^h\ 35^m$ was partially clear in the east. Stars visible down to about 4^m sometimes. Certainly no fine shower in progress.

14	51	? L	$1\frac{1}{2}$	S	

From $14^h\ 45^m$ to $14^h\ 55^m$ was partially clear.

15	8	L	V. br.		Through thick cloud
15	27		General flash; unlocatable		
15	40	L	Br.		
15	48	Not a Leonid			
16	0	? L	2	NS	
16	5	L			
16	6	L	Br.	S	
16	9	L			
16	11	? L			
16	$16\frac{1}{2}$	L			
16	17	L	2	NS	
16	18	L	1	NS	
16	23	L	1		
16	24	L			
16	32	L	3		
16	33	Not a Leonid	V. bright, long green streak		
16	35	? L	Extremely bright.		Slow, lit up sky

G.M.T.		Magnitude.	Streak.
16 40	L	Br.	
16 44	Not a Leonid	Faint.	
16 44½	L	1	S
16 45	L	1	S
16 47	L	2	
16 47½	L	2	

From $16^h\ 0^m$ to $16^h\ 50^m$ it was partially clear, and a good proportion of the brighter meteors must have been recorded. After this the clouds gradually became thicker.

16 51	L		
16 52	L		
16 56		A flash	
16 59	L	Faint	
17 7		A flash	
17 12	?L	2	NS
17 15	L	3	S
17 16	?L	2	
17 40	?L	1	S

In the column headed "streak" the letter S means that it is recorded that the meteor left a streak, but that no details of its colour are given. The letters NS mean that it is recorded that no streak was visible.

It is quite probable that some of the meteors recorded as *Leonids*, but with the note "no streak," were really from the radiants near *Leo*, which are active about the same time. In other cases the streaks were doubtless hidden by cloud.

If on comparison with the results of observers in other longitudes it is found that we were fortunate enough to have a partial view of the maximum of this year's shower, I think we may conclude from these observations that the maximum did not furnish a very brilliant display, and that when the Earth in 1898 passed through the node of the *Leonids'* orbit, the front of the main group of meteors was still at some distance.

Cambridge Observatory:
1898 *November* 18.

Ephemeris for Physical Observations of the Moon for the First Half of 1899. By A. C. D. Crommelin.

Greenwich Noon.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
1899.		°	°	°	°	°	°
Jan.	1	143·21	+0·06	−4·58	+5·32	7·02	40·7
	2	155·36	0·09	5·71	6·09	8·34	43·2
	3	167·50	0·11	6·63	6·61	9·35	45·1
	4	179·65	0·14	7·30	6·82	10·00	47·0
	5	191·81	0·17	7·63	6·70	10·15	48·7
	6	203·97	0·20	7·59	6·24	9·79	50·6
	7	216·14	0·23	7·12	5·41	8·97	52·8
	8	228·32	0·26	6·22	4·23	7·53	55·8
	9	240·51	0·29	4·91	2·76	5·65	60·7
	10	252·69	0·32	3·24	+1·06	3·40	71·9
	11	264·89	0·35	−1·33	−0·74	1·52	119·1
	12	277·08	0·38	+0·71	2·50	2·60	195·9
	13	289·28	+0·41	2·70	4·07	4·88	213·5
	14	301·47	0·44	4·48	5·36	6·97	219·9
	15	313·65	0·47	5·96	6·23	8·60	223·7
	16	325·83	0·49	7·01	6·70	9·67	226·3
	17	338·00	0·52	7·57	6·78	10·14	228·2
	18	350·16	0·55	7·74	6·48	10·06	230·1
	19	2·32	0·57	7·47	5·86	9·49	231·9
	20	14·47	0·60	6·82	4·97	8·46	233·9
	21	26·62	0·62	5·89	3·87	7·07	236·7
	22	38·76	0·65	4·74	2·62	5·40	241·1
	23	50·90	0·67	3·44	−1·26	3·65	249·9
	24	63·04	0·69	2·06	+0·13	2·06	273·6
	25	75·17	+0·71	+0·64	1·52	1·64	337·2
	26	87·31	0·74	−0·75	2·84	2·93	14·8
	27	99·44	0·76	2·10	4·03	4·55	27·5
	28	111·58	0·78	3·35	5·06	6·07	33·5
	29	123·71	0·80	4·48	5·88	7·41	37·3
	30	135·85	0·83	5·47	6·43	8·42	40·4
	31	147·99	0·85	6·28	6·70	9·18	43·1
Feb.	1	160·14	0·88	6·88	6·65	9·56	46·0
	2	172·29	0·90	7·22	6·28	9·53	49·0
	3	184·45	+0·93	−7·28	+5·58	9·17	52·5

Greenwich Noon.		Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Lat. of the Earth.	Combined Amount.	Direction.
1899. Feb.	4	196°·62	+0°·95	−7°·00	+4°·55	8°·33	57°·0
	5	208·79	0·97	6·36	3·23	7·12	63·1
	6	220·97	+1·00	5·34	+1·68	5·61	72·5
	7	233·15	1·02	3·95	−0·02	3·95	90·3
	8	245·35	1·04	2·25	1·75	[illegible]	127·9
	9	257·55	1·07	−0·34	3·38	3·41	174·2
	10	269·75	1·09	+1·65	4·77	5·06	199·1
	11	281·95	1·11	3·54	5·82	6·81	211·3
	12	294·15	1·13	5·18	6·46	8·27	218·7
	13	306·34	1·15	6·43	6·66	9·26	224·0
	14	318·53	1·17	7·21	6·47	9·66	228·1
	15	330·71	1·18	7·49	5·91	9·51	231·7
	16	342·89	1·20	7·29	5·07	8·89	235·2
	17	355·06	1·21	6·67	4·01	7·80	239·0
	18	7·22	+1·23	5·71	2·78	6·34	244·1
	19	19·38	1·24	4·51	1·46	4·74	252·1
	20	31·54	1·26	3·17	−0·09	3·17	268·4
	21	43·69	1·27	1·72	+1·28	2·15	306·7
	22	55·84	1·28	+0·30	2·58	2·61	353·4
	23	67·99	1·30	−1·05	3·78	3·93	15·5
	24	80·14	1·31	2·29	4·82	5·35	25·4
	25	92·28	1·32	3·38	5·66	6·57	30·8
	26	104·42	1·33	4·30	6·24	7·55	34·6
	27	116·57	1·34	5·04	6·54	8·24	37·6
	28	128·71	1·36	5·60	6·53	8·62	40·6
March	1	140·86	1·37	5·98	6·20	8·62	44·0
	2	153·02	+1·38	6·17	5·54	8·27	48·1
	3	165·18	1·40	6·15	4·58	7·69	53·3
	4	177·34	1·41	−5·90	+3·36	6·78	60·3
	5	189·52	1·42	−5·40	+1·91	5·72	70·5
	6	201·70	1·43	4·62	+0·32	4·62	86·0
	7	213·89	1·45	3·55	1·32	3·80	110·4
	8	226·09	+1·46	2·20	2·90	3·65	142·8
	9	238·29	1·47	−0·63	4·30	4·34	171·6
	10	250·50	1·48	+1·06	5·43	5·54	191·0
	11	262·71	1·49	2·73	6·19	6·75	203·8
	12	274·93	+1·49	+4·24	−6·52	7·76	213·0

Greenwich Noon.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
1899.		°	°	°	°	°	°
March	13	287·14	+1·50	+5·44	−6·44	8·44	220·2
	14	299·35	1·51	6·24	5·97	8·61	226·3
	15	311·55	1·51	6·56	5·18	[illegible]·35	231·7
	16	323·75	1·51	6·43	4·13	7·65	237·3
	17	335·95	1·51	5·87	2·92	6·57	243·5
	18	348·14	1·51	4·95	1·59	5·20	252·2
	19	0·32	1·51	3·78	−0·22	3·78	266·7
	20	12·50	+1·51	2·44	+1·13	2·68	294·8
	21	24·67	1·51	+1·03	2·44	2·66	337·1
	22	36·84	1·51	−0·36	3·63	3·66	5·7
	23	49·01	1·51	1·64	4·68	4·96	19·3
	24	61·17	1·51	2·77	5·53	6·19	26·6
	25	73·33	1·51	3·69	6·14	7·18	31·0
	26	85·49	1·51	4·38	6·47	7·83	34·1
	27	97·65	1·51	4·84	6·49	8·11	36·7
	28	109·80	1·51	5·08	6·18	7·97	39·4
	29	121·96	1·51	5·12	5·52	7·56	42·9
	30	134·13	1·50	5·00	4·59	6·86	47·4
	31	146·29	1·50	4·71	3·38	5·79	54·3
April	1	158·47	+1·50	4·29	1·96	4·72	65·4
	2	170·65	1·50	3·70	+0·40	3·74	83·8
	3	182·83	1·50	2·97	−1·19	3·21	111·8
	4	195·03	1·50	2·06	2·74	3·42	143·1
	5	207·23	1·49	−0·99	4·13	4·25	166·5
	6	219·44	1·49	+[illegible]	5·26	5·26	182·4
	7	231·66	1·49	1·49	6·07	6·25	193·8
	8	243·89	1·48	2·74	6·49	7·07	202·9
	9	256·11	1·47	3·88	6·50	7·54	210·8
	10	268·34	1·47	4·77	6·12	7·77	217·9
	11	280·57	1·46	5·34	5·38	7·59	224·8
	12	292·79	1·45	5·53	4·37	7·02	231·7
	13	305·02	+1·44	5·32	3·15	6·17	239·4
	14	317·23	1·42	4·74	1·81	5·07	249·1
	15	329·45	1·41	3·84	−0·41	3·88	263·9
	16	341·65	1·40	2·69	+0·98	2·85	290·0
	17	353·86	1·38	1·39	2·32	2·71	329·1
	18	6·06	1·37	+0·01	3·54	3·54	359·8
	19	18·25	+1·35	−1·32	+4·61	4·79	16·0

Greenwich Noon.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
1899. April	20	30·44°	+1·34°	−2·56°	+5·49°	6·04°	25·0°
	21	42·62	1·33	3·60	6·14	7·12	30·4
	22	54·81	1·31	4·40	6·52	7·89	34·0
	23	66·99	1·30	4·91	6·59	8·24	36·7
	24	79·16	1·28	5·13	6·33	8·17	39·0
	25	91·33	+1·27	5·07	5·72	7·66	41·5
	26	103·50	1·26	4·76	4·80	6·77	44·8
	27	115·68	1·24	4·24	3·58	5·55	49·8
	28	127·85	1·23	3·56	2·13	4·17	59·1
	29	140·03	1·22	2·77	+0·54	2·83	79·0
	30	152·22	1·20	1·90	−1·10	2·18	120·0
May	1	164·41	1·19	0·98	2·67	2·86	159·8
	2	176·61	1·17	−0·01	4·09	4·09	179·9
	3	188·82	1·16	+0·96	5·25	5·35	190·4
	4	201·04	1·14	1·94	6·09	6·39	197·7
	5	213·26	1·13	2·86	6·57	7·16	203·5
	6	225·49	1·11	3·68	6·64	7·57	209·0
	7	237·73	+1·09	4·36	6·33	7·66	214·6
	8	249·97	1·07	4·81	5·66	7·41	220·4
	9	262·21	1·05	4·98	4·70	6·87	226·6
	10	274·45	1·03	4·87	3·50	5·99	234·3
	11	286·69	1·00	4·45	2·15	4·94	244·2
	12	298·93	0·98	3·74	−0·72	3·81	259·1
	13	311·16	+0·96	2·75	+0·72	2·83	284·7
	14	323·39	0·94	1·60	2·09	2·63	322·5
	15	335·62	0·91	+0·30	3·38	3·38	354·9
	16	347·84	0·89	−1·04	4·50	4·63	13·0
	17	0·05	0·86	2·36	5·44	5·93	23·5
	18	12·27	0·84	3·57	6·14	7·12	30·2
	19	24·47	0·82	4·58	6·59	8·04	34·8
	20	36·67	0·79	5·33	6·74	8·56	38·3
	21	48·87	0·77	5·77	6·56	8·72	41·3
	22	61·06	0·75	5·87	6·05	8·41	44·1
	23	73·25	0·73	5·62	5·19	7·64	47·3
	24	85·43	0·71	5·04	4·02	6·45	51·4
	25	97·62	+0·69	4·17	2·58	4·92	58·3
	26	109·80	0·66	3·08	+0·95	3·23	72·9
	27	121·98	+0·64	−1·86	−0·75	2·01	112·0

Greenwich Noon.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
1899. May	28	134·17°	+0·62°	−0·57°	−5·42°	5·49°	166·6°
	29	146·37	0·59	+0·72	3·93	4·01	190·4
	30	158·57	0·57	1·94	5·18	5·54	200·6
	31	170·78	0·55	3·02	6·10	6·83	206·3
June	1	183·00	0·53	3·94	6·64	7·70	210·7
	2	195·23	0·50	4·67	6·78	8·20	214·6
	3	207·46	0·47	5·18	−6·53	8·36	218·4
	4	219·70	0·45	5·41	5·93	8·06	222·6
	5	231·94	0·42	5·47	5·08	7·44	227·5
	6	244·19	+0·40	5·24	3·87	6·50	233·6
	7	256·44	0·37	4·76	2·54	5·38	241·9
	8	268·69	0·34	4·05	−1·12	4·21	254·5
	9	280·93	0·31	3·13	+0·34	3·16	276·2
	10	293·18	0·28	2·03	1·76	2·68	310·9
	11	305·43	0·25	+0·79	3·09	3·18	345·6
	12	317·67	0·22	−0·52	4·28	4·32	7·0
	13	329·91	0·20	1·87	5·27	5·59	19·5
	14	342·14	0·17	3·18	6·05	6·84	27·7
	15	354·37	0·14	4·38	6·56	7·87	33·7
	16	6·59	0·11	5·41	6·80	8·70	38·5
	17	18·81	0·09	6·18	6·73	9·15	42·6
	18	31·02	0·06	6·65	6·33	9·18	46·4
	19	43·23	0·03	6·74	5·60	8·76	50·3
	20	55·43	+0·01	6·46	4·54	7·88	54·9
	21	67·62	−0·02	5·78	3·19	6·59	61·1
	22	79·82	0·04	4·71	+1·61	4·99	71·1
	23	92·00	0·07	3·34	−0·12	3·34	92·1
	24	104·19	0·09	1·74	1·86	2·55	136·9
	25	116·38	0·11	−0·02	3·49	3·49	179·6
	26	128·57	0·14	+1·69	4·87	5·16	199·1
	27	140·77	0·16	3·25	5·92	6·75	208·8
	28	152·98	0·19	4·60	6·57	8·02	215·0
	29	165·19	0·22	5·64	6·81	8·85	219·6
	30	177·41	0·24	6·34	6·63	9·15	223·7
July	1	189·64	−0·27	+6·69	−6·09	9·03	227·7

This ephemeris has been computed in the same manner and with the same constants as those in recent years. The inclination of the Moon's equator to the ecliptic is assumed to be 1°·523, the

value adopted by the *Connaissance des Temps*; that given by the *Nautical Almanac* is $1^\circ{\cdot}536$.

The principal term of the physical libration in longitude has been applied as before, the expression for it being $-0^\circ{\cdot}037 \times$ Sun's mean anomaly.

The colongitude of the Sun is 90° (or 450°) *minus* his selenographical longitude. It also is the selenographical longitude of the morning terminator reckoned eastward from the mean centre of the disc. Hence its value is approximately 270°, 0°, 90°, 180° at new Moon, first quarter, full Moon, last quarter respectively. The longitude of the evening terminator is of course 180° greater or less than that of the morning one.

When the geocentric libration in longitude is positive, the region brought into view is on the west limb; when negative, on the east.

When the geocentric libration in latitude is positive, the region brought into view is at the Moon's north pole; when negative, at the south.

The column "Combined Amount" gives the distance between the apparent and mean centres of the disc, and the column "Direction" gives the position angle of the apparent centre from the mean centre, or, which is the same thing, the position angle of the region which is most carried into view by libration. The angles are reckoned eastward from the northern extremity of the Moon's axis.

The terms "East" and "West" are used throughout with reference to our sky, and not as they would appear to an observer on the Moon.

Attention may be drawn to the unusually favourable conditions for studying the regions adjacent to the north-east and south-west limbs, which will occur on January 5 and 17 respectively. February 1, 14, 28 are also favourable, but to a less extent.

It has been suggested that this ephemeris should be made for Greenwich midnight instead of noon, and I propose in future to adopt this course, which will obviously be more convenient for European observers. A similar course in the Planetary Ephemerides would be desirable, but it would add considerably to the labour of computation, as the *Nautical Almanac* gives the places of the planets for noon and not for midnight.

Benvenue, Ulundi Road, Blackheath, S.E.:
1898 *December* 8.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

Vol. LIX. JANUARY 13, 1899. No. 3

Sir R. S. Ball, M.A., LL.D., F.R.S., President, in the Chair.

Charles Lewis Brook, M.A., F.R.Met.Soc., Harewood Lodge, Meltham, Huddersfield;
Arthur Hands, L.R.C.P., M.R.C.S., Inkerman House, Wednesfield Road, Wolverhampton;
Samuel Henry Harrison, F.R.G.S., Frederick Road, Edgbaston, Birmingham;
Arthur Robert Hinks, M.A., Observatory, Cambridge; and
Worcester R. Warner, Cleveland, Ohio, U.S.A.,

were balloted for and duly elected Fellows of the Society.

The following candidate was proposed for election as a Fellow of the Society:—

Colonel Thomas Davies Sewell, Clerk to the Spectacle Makers' Company, 29 Grosvenor Road, S.W. (proposed by Sir R. S. Ball).

Seventy-two presents were announced as having been received since the last meeting, including, amongst others:—

O. Backlund, Bewegung kleiner Planeten des Hecuba-Typus; O. Backlund, Calculs et recherches sur la comète d'Encke; A. H. Fison, Recent advances in Astronomy; presented by the

Authors; Kasan Observatory, Catalogue de 4281 étoiles entre +74° 40′ et +80° 20′, presented by the Observatory; L. Weinek, Photographisches Mond-Atlas, Heft 4, presented by Professor Weinek; Photographs showing trails of minor planets, &c. (copies on glass), presented by Professor Max Wolf.

The Total Solar Eclipse of 1898 *January* 22. *Final Reports on the Results obtained.*

The preliminary reports of the observers sent out by the Joint Permanent Eclipse Committee have been published simultaneously in the *Proceedings of the Royal Society* and in the *Monthly Notices*. The final reports, containing the discussion of results, will appear as a volume of the *Philosophical Transactions*, which will be distributed to Fellows of this Society as well as to Fellows of the Royal Society.

It was suggested to the Joint Permanent Eclipse Committee by the Council of the Royal Astronomical Society that possibly some observers, other than those sent out directly by the Committee, might desire to submit their final reports for publication in this volume. The suggestion was favourably received by the Committee, who have signified to the Council of the Royal Astronomical Society their willingness to "receive and consider any papers on the late eclipse not previously published."

The Council of the Royal Astronomical Society have accordingly directed the secretaries to make generally known this decision of the Joint Permanent Eclipse Committee by inserting this paragraph in the *Monthly Notices*.

H. F. Newall, }
H. H. Turner, } *Secretaries.*

Communication concerning the publication of an Annual Astronomical Report. By Walter F. Wislicenus, Ph.D., Professor at the University, Strassburg.

I intend to publish an *Astronomischer Jahresbericht mit Unterstützung der Astronomischen Gesellschaft* (Astronomical Yearly Report, aided by the Astronomische Gesellschaft). It will give short reports of all the works on astronomy, astrophysics and geodesy, both practical and theoretical, which have appeared during the year. The first volume will appear in 1900, and will contain reports of all the publications of 1899. Not wishing to overlook anything, I should be much obliged if all authors

of such publications, appearing as single books, or articles in journals not usually destined and used for astronomical publications, would kindly communicate them to me.

Strassburg (Elsass), Nicolausring 37,
1899 *January.*

Note on Dr. Rambaut's Remarks in the "Monthly Notices" for November 1898. By David Gill, C.B., F.R.S., &c., Her Majesty's Astronomer at the Cape of Good Hope.

I would gladly allow the existing controversy with Dr. Rambaut to rest on what has been written, were it not that in his final remarks (*Monthly Notices*, lix. p. 3) Dr. Rambaut makes no admission of the error of his original conclusion—viz. that atmospheric chromatic dispersion may be regarded as the origin of certain systematic errors which entered into my observations for determining the parallax of *a Centauri*.

It is this conclusion, and this alone, which I set out to dispute. It is the only point of fundamental importance in the discussion, and Dr. Rambaut persistently evades it by introducing discussions and remarks on side issues.

It is but fair to ask Dr. Rambaut whether he *now* maintains that his original re-discussion of my observations for the parallax of α_2 *Centauri* can be regarded as a legitimate one, and as affording evidence of the existence of a term depending on

$$\tan \zeta \cos (p-q).$$

If he does not reply I must conclude that he admits his original explanation and solution to be erroneous.

On a Method of Obtaining Perfectly Circular Dots unaffected by phase, and their employment in determining the Pivot Errors of the Cape Transit Circle. By David Gill, C.B., F.R.S., H.M. Astronomer at the Cape.

One of the chief difficulties in determining the errors of pivots of Transit Circles is that of obtaining a mark which, rotating with the pivot, can be bisected by the observer with perfect certainty in all positions of the telescope.

When the pivots of a transit circle are not perforated, as in the old Cambridge transit instrument, a dot may be engraved on the end of each pivot or upon plates attached to the ends of the pivots, and the vertical and horizontal coordinates of these dots in different positions of the instrument may be measured by a micrometer which is attached to the pier or to

the support of the pivot. But it is beyond the instrument maker's art to engrave a dot which is at once sufficiently small and sufficiently true and clean at the edge to form a reliable mark for the purpose; at least I have never seen an engraved dot (when its surrounding field is illuminated by reflected light) so sharp and clean in outline that one could feel assured of estimating the same centre when different diameters are exposed to the same direction of illumination. When the pivots are hollow, as in the Greenwich and Cape Transit Circles, and an object-glass is fixed in one of the pivots, whilst a metal plate perforated by a small hole is fixed in the opposite pivot in the principal focus of the object-glass, we have a rotating collimator, and, by measuring the coordinates of its axis in rotation by means of a fixed collimator with a micrometer eye-end, we can determine the combined effects of the errors of both pivots on the level and azimuth of their true axis.

We have here also the advantage of employing a point of reference which is not subject to phase by varying direction of illumination, but there remains the difficulty of making a hole sufficiently small, and at the same time perfectly true and sharp in its circular outline.

With an apparatus of this kind, and an observing telescope resting on Y bearings fixed to a wooden bracket bolted to the pier, the combined errors of the pivots of the Cape Transit Circle were investigated by Sir Thomas Maclear soon after the erection of the instrument, and subsequently the operation was repeated by Mr. Stone.

I also made an attempt in 1880 to determine the pivot errors in this way, but the observing telescope was not sufficiently stable, the hole was not sharp and true enough in outline, nor could it be brought sufficiently coincident with the axis of rotation to permit a complete distinction between the errors of the micrometer-screw and the errors of the pivots.

The results of all these investigations tended to show that the pivot errors were smaller than the errors which were inseparable from the defects of the apparatus.

In 1897 I had the following changes in the apparatus made by Mr. Simms:—

1. The object-glass of the western pivot was refigured and very perfectly secured in its mounting.
2. In lieu of an image of a small hole in the focus of the pivot object-glass, the following method was adopted for forming a perfectly opaque and circular dot:—

A circular plate of thin glass (the cover of a microscope slide) was held for an instant over the fumes of boiling mercury. On examination under the microscope, the glass is seen to be covered with numerous minute spheres of mercury which have been condensed on its surface. By means of a camel's hair-brush or a pointed bit of wood all these

spheres, except one near the centre of the plate, were removed. A similar circular cover was then heated over a spirit flame till a small portion of Canada balsam, placed on its upper surface, is melted. This latter disc is then placed with its balsam-covered face upon the surface of the first disc, and the two discs are pressed together. When the Canada balsam has completely set, we have the small mercury sphere securely held in its place between the glass discs. The single disc thus formed was then mounted on the pivot in a suitable holder, which permitted the dot to be truly focussed in the principal focus of the object-glass in the opposite pivot, and to be centred by suitable adjusting screws, in the axis of the pivots.

3. In lieu of the 46-inch telescope previously used as the fixed collimator, the beautiful object-glass of the old Dollond 10-foot transit instrument was mounted in a suitable tube, one end of which was supported on an iron standard resting on the western pier, whilst the eye-end passed through a hole made in the solid masonry of the western wall of the transit circle room, and was supported there by another iron standard resting in the wall.
4. The Repsold micrometer of the photographic measuring apparatus was firmly mounted at the eye-end of this telescope, the axis of one of its screws being made truly vertical by a plumb line, and the readings were made by an assistant in the adjoining room.

When this apparatus was properly focussed and adjusted and the glass plate was illuminated by an electric incandescent lamp with frosted glass bulb placed in the direction of the axis of rotation at about 4 feet distant from the eastern pivot, the mercury dot appeared in a bright field as a perfectly sharp and circular black disc of about three seconds of arc in diameter, capable of the most perfect bisection, and so nearly centred as to appear at rest in the field of view whilst the telescope was rotated.

Observations were then made as follows :—

The setting circle was pointed to N.P.D. 0°, and the mercury dot was bisected by the horizontal screw ; then the setting was changed to N.P.D. 5° and the dot again bisected, and so on till the dot had been bisected at each 5th degree of the circle readings. The operation was then immediately repeated in the reverse order.

A similar operation was then performed with the vertical screw.

Four such operations constituted a complete group. The means of all the readings were then taken for the observations with each screw, and the respective means were subtracted from the mean readings for each 5th degree of N.P.D.

The results are given in the following table :—

N.P.D.	Horizontal Screw Group. I.	II.	Vertical Screw Group. I.	II.	N.P.D.	Horizontal Screw Group. I.	II.	Vertical Screw Group. I.	II.
°	d	d	d	d	°	d	d	d	d
0	+0·46	+0·45	−0·73	−0·95	180	−0·85	−0·81	+0·33	+0·27
5	+ ·25	+0·20	−0·93	−0·86	185	−1·13	−0·98	+0·51	+0·38
10	+ ·45	+0·13	−1·17	−0·81	190	−0·94	−0·77	+0·88	+0·79
15	+ ·15	−0·12	−1·18	−1·12	195	−0·78	−0·77	+1·13	+1·29
20	+ ·05	−0·07	−1·39	−1·17	200	−0·81	−0·81	+1·16	+1·66
25	+ ·08	−0·26	−1·55	−1·33	205	−0·86	−0·58	+1·10	+1·32
30	+ ·09	−0·03	−1·50	−1·55	210	−0·54	−0·41	+1·31	+1·46
35	+ ·14	−0·03	−1·43	−1·28	215	−0·40	−0·14	+1·45	+1·64
40	+ ·09	−0·14	−1·60	−1·58	220	−0·24	−0·27	+1·56	+1·66
45	+ ·18	+0·06	−1·48	−1·97	225	−0·10	−0·04	+1·41	+1·79
50	+ ·11	−0·07	−1·67	−1·52	230	−0·16	+0·06	+1·36	+1·64
55	− ·01	+0·01	−1·55	−1·80	235	+0·14	+0·10	+1·49	+1·59
60	− ·05	+0·05	−1·45	−1·53	240	+0·20	+0·13	+1·20	+1·58
65	− ·24	−0·36	−1·55	−1·63	245	−0·06	+0·36	+1·48	+1·48
70	− ·39	−0·82	−1·64	−1·75	250	+0·16	+0·36	+1·19	+1·37
75	− ·59	−0·68	−1·30	−1·42	255	+0·49	+0·53	+1·13	+1·23
80	− ·93	−0·87	−1·00	−1·23	260	+0·51	+0·68	+1·16	+1·24
85	−1·09	−1·04	−0·74	−0·98	265	+0·53	+0·75	+1·06	+0·81
90	−1·08	−1·11	−0·58	−0·65	270	+0·80	+0·71	+0·96	+0·68
95	−1·01	−1·13	−0·42	−0·66	275	+1·11	+0·88	+0·75	+0·94
100	−1·10	−0·99	−0·18	−0·38	280	+0·95	+0·86	+0·41	+0·58
105	−1·09	−1·07	+0·11	−0·03	285	+1·11	+0·78	+0·33	+0·52
110	−0·79	−0·87	+0·68	+0·19	290	+1·26	+1·05	+0·51	+0·52
115	−0·85	−0·82	+0·73	+0·46	295	+1·35	+1·15	+0·23	+0·68
120	−0·86	−0·98	+1·01	+0·54	300	+1·53	+1·33	+0·06	+0·56
125	−0·74	−0·74	+0·91	+0·24	305	+1·51	+1·47	+0·18	+0·41
130	−0·95	−0·62	+0·91	+0·32	310	+1·69	+1·35	−0·05	+0·13
135	−0·88	−0·66	+0·80	+0·31	315	+1·66	+1·55	−0·53	−0·30
140	−0·86	−0·82	+0·73	+0·29	320	+1·59	+1·43	−0·75	−0·30
145	−0·88	−0·82	+0·44	+0·44	325	+1·53	+1·40	−0·55	−0·93
150	−1·20	−0·96	+0·80	+0·66	330	+1·26	+1·15	−0·83	−0·78
155	−0·96	−0·88	+0·24	+0·44	335	+1·43	+1·20	−0·84	−0·92
160	−0·79	−0·63	+0·30	+0·27	340	+1·03	+1·05	−0·92	−1·01
165	−0·76	−0·62	−0·11	+0·12	345	+0·85	+0·90	−0·87	−0·80
170	−0·53	−0·77	+0·19	+0·19	350	+0·94	+0·85	−1·08	−0·68
175	−0·94	−0·82	+0·05	+0·18	355	+0·55	+0·82	−0·73	−0·87

1 Division $= 0''\cdot312$.

Increased + readings of the horizontal screw correspond with motion of the mercury-dot on the eastern pivot towards the north.

Increased + readings of the vertical screw indicate that the mercury-dot on the eastern pivot is moving downwards.

If the pivots were truly circular and the observations were made without error, the figures of the preceding table would have their origin in non-coincidence of the mercury-dot with the axis of rotation, and would therefore be rigorously represented by the expressions:

$$\text{Vertical measures} = a \cos \text{N.P.D} - b \sin \text{N.P.D.}$$

$$\text{Horizontal measures} = a \sin \text{N.P.D.} + b \cos \text{N.P.D.}$$

Forming equations of this type and solving by least squares we get:

		a d	b d
From the vertical measures, Group	I.	$-1\cdot11$	$+0\cdot70$
,, ,, ,,	II.	$-1\cdot07$	$+0\cdot90$
,, horizontal measures, Group	I.	$-0\cdot80$	$+0\cdot77$
,, ,, ,,	II.	$-0\cdot79$	$+0\cdot68$
Means	...	$-0\cdot94$	$+0\cdot76$

Adopting these mean values of a and b, and substituting them in the original equations, we get the following values (O – C), representing the errors of inclination and azimuth of the axis, which are due to the combined errors of the two pivots.

For convenience the results are converted into seconds of time at the equator, and the sign of the O – C residuals has been changed in the horizontal measures so that the + sign signifies an error of the western pivot in azimuth towards the north. In this way the signs of the tabular errors correspond with the signs which are habitually used in the reduction of our meridian observations, viz. the sign + indicates that the western pivot of the horizontal axis is too high, and that the line of collimation, when the observer is looking towards the south, points to the west of true south.

It should be remarked that these errors are entirely independent of any law, and the regular run which they exhibit shows how accurate were the observations.

Table of Pivot Errors.

N.P.D.	Column I. *Level* Western Pivot too high.	Column II. *Azimuth* Western Pivot too far North.	N.P.D.	Column I. *Level* Western Pivot too high.	Column II. *Azimuth* Western Pivot too far North.
°	s	s	°	s	s
0	+ 0·002	+ 0·006	180	− 0·013	+ 0·001
5	+ 2	+ 10	185	− 12	+ 8
10	+ 1	+ 6	190	− 5	+ 6
15	− 1	+ 10	195	+ 2	+ 6
20	− 3	+ 8	200	+ 6	+ 9
25	− 6	+ 8	205	+ 1	+ 9
30	− 7	+ 3	210	+ 4	+ 6
35	− 3	+ 1	215	+ 7	− 4
40	− 8	+ 0	220	+ 8	+ 6
45	− 11	− 5	225	+ 8	+ 4
50	− 9	− 5	230	+ 7	+ 6
55	− 11	− 7	235	+ 8	+ 4
60	− 7	− 9	240	+ 5	+ 6
65	− 10	− 5	245	+ 8	+ 8
70	− 14	− 0	250	+ 5	+ 7
75	− 8	− 2	255	+ 4	+ 4
80	− 4	+ 2	260	+ 6	+ 4
85	− 0	+ 4	265	+ 2	+ 5
90	+ 3	+ 3	270	+ 1	+ 4
95	+ 3	+ 1	275	+ 4	+ 0
100	+ 6	− 0	280	− 2	+ 3
105	+ 11	− 1	285	− 1	+ 4
110	+ 17	− 6	290	+ 3	− 0
115	+ 19	− 7	295	+ 4	− 2
120	+ 20	− 6	300	+ 2	− 5
125	+ 14	− 10	305	+ 5	− 6
130	+ 12	− 9	310	+ 1	− 6
135	+ 9	− 9	315	− 6	− 9
140	+ 6	− 7	320	− 6	− 7
145	+ 2	− 6	325	− 9	− 6
150	+ 6	− 1	330	− 8	− 2
155	− 4	− 4	335	− 7	− 5
160	− 7	− 7	340	− 7	− 0
165	− 15	− 6	345	− 3	+ 2
170	− 13	− 5	350	− 2	+ 0
175	− 16	+ 1	355	+ 1	+ 3

The corrections applicable to observations with the Transit Circle on account of these errors of the pivots can, of course, be best applied to the original observations and determinations of instrumental adjustment; but as these observations were all reduced and printed before the pivot errors were definitely determined, it remains to consider how their effects on the Cape Catalogues for 1885 and 1890 can be computed.

Effect of the Pivot Errors in the determination of Collimation.

The collimation is determined by directing the telescope to two horizontal collimators, whose axes have previously been adjusted to coincidence. For sake of simplicity we shall assume that the common axis of both collimators lies true north and south.

When the Transit Circle is directed to the north collimator, the N.P.D. reading, in round numbers, is 34°, and when directed to the south collimator, 214°. Our table of pivot errors shows that, in these circumstances, the telescope points $0^s{\cdot}001$ E. of north, and $0^s{\cdot}005$ W. of south. The R.A. micrometer of the Transit Circle is graduated, so that an increase of the readings of the micrometer carries the whole system of wires to the west; that is to say, if the axis of the telescope is defined by any wire, increased readings of the micrometer imply that this axis is directed more towards the east. Thus the effect of pivot error is to make the readings on the north collimator too small, because by pivot error the telescope already points E. of true north.

Thus the correction to the readings on the N. collimator is	$+\ 0^s{\cdot}001$
„ „ „ S. „	$-\ {\cdot}005$
and the correction to the previously adopted reading for geometric collimation becomes	$-\ 0^s{\cdot}002$

Thus every observed transit requires a correction, on account of the error in collimator-determination produced by pivot error, of

$$\Delta c = -0^s{\cdot}002 \times \text{collimation factor.}$$

Effect of Pivot Errors on the Determination of Level.

The level error is determined by observing the micrometer reading for coincidence of the middle wire with its image as reflected from a pool of mercury. The Nadir reading, in round numbers, is 304°. The table of pivot errors, column 1, shows that at N.P.D. 304° the western end of the axis is too high by $0^s{\cdot}004$; therefore a correction of $-0^s{\cdot}004$ is required to find the reading for coincidence if the pivots were without error.

We have already found that the reading for geometrical collimation requires, on account of pivot errors, the correction $-0^s{\cdot}002$; hence, in the expression

Level error (high W) = "Reading for coincidence" − "Reading for collimation,"

we have to apply the correction

$$\Delta b = -0^{s}{\cdot}004 - (-0^{s}{\cdot}002) = -0^{s}{\cdot}002.$$

Thus the correction to the time of transit of any particular star on account of error of level produced by pivot errors is

$$\left\{\left(\begin{array}{c}\text{Tabular correction from Col. I.,}\\ \text{argument N.P.D.}\end{array}\right) - 0^{s}{\cdot}002\right\} \times \text{Level factor.}$$

Effect of Pivot Errors on the Determination of Azimuth.

To represent general facts as nearly as possible, we shall assume that on every night azimuth was determined by observation of the transit of one circumpolar star of N.P.D. 178° at upper culmination, and of the transit of a star of the same declination at lower culmination (N.P.D. 182°).*

The time of upper transit of this imaginary circumpolar star will require the following corrections on account of pivot error :

			Factors.		s	
Collimation	$-0^{s}{\cdot}002$	×	$+28{\cdot}65$	=	$-0{\cdot}0573$	
Level	$(-0^{s}{\cdot}014 - 0^{s}{\cdot}002)$	×	$+16{\cdot}82$	=	$-0{\cdot}2691$	$= \Delta T_u = -0^{s}{\cdot}350$
Azimuth	$+0^{s}{\cdot}001$	×	$-23{\cdot}20$	=	$-0{\cdot}0232$	

Similarly at lower transit :

			Factors.		s	
Collimation	$-0^{s}{\cdot}002$	×	$-28{\cdot}65$	=	$+0{\cdot}0573$	
Level	$(-0^{s}{\cdot}013 - 0^{s}{\cdot}002)$	×	$-15{\cdot}16$	=	$+0{\cdot}2274$	$= \Delta T_l = +0^{s}{\cdot}382.$
Azimuth	$+0^{s}{\cdot}004$	×	$+24{\cdot}32$	=	$+0{\cdot}0973$	

The correction to the original azimuth on account of pivot errors will therefore be

$$\Delta a = -\left(\frac{\Delta T_u - \Delta T_l}{f_u - f_l}\right) = -0^{s}{\cdot}0154,$$

where ΔT_u and ΔT_l are the corrections above computed, and f_u and f_l are the azimuth factors at upper and lower culmination respectively.

Thus the correction to the time of transit of any particular star on account of error of azimuth produced by pivot errors is

$$\left\{\left(\begin{array}{c}\text{Tabular correction from Col. II.}\\ \text{Argument N.P.D.}\end{array}\right) - 0^{s}{\cdot}0154\right\} \times \text{azimuth factor.}$$

Effect of Pivot Errors on the Determination of Clock-correction.

The clock stars employed were generally between declinations +10° and −10°, a very few only being used beyond these limits ;

* It will be seen from the tables of azimuth determination in the Cape annual volumes that, on nights when star positions were determined, the azimuth always depended upon at least one upper and one lower culmination of circumpolar stars, but generally upon two upper and two lower culminations.

their mean N.P.D. may be taken as 90°. The mean of the corrections for N.P.D. 80°, 85°, 90°, 95°, and 100° on account of pivot error are, from our table:

In level $+0^{s}{\cdot}002$ and in azimuth $+0^{s}{\cdot}002$.

The time of transit of a clock star will thus require the following corrections on account of pivot error:

$$\begin{array}{l|l} & \qquad\qquad\text{Factors.} \qquad\quad \text{s} \\ \text{Collimation} & -0^{s}{\cdot}002 \qquad\quad \times +1{\cdot}000 = -\,0{\cdot}002 \\ \text{Level} & (+0^{s}{\cdot}002-0^{s}{\cdot}002)\times +0{\cdot}830 = \quad {\cdot}000 \\ \text{Azimuth} & (+0^{s}{\cdot}002-0^{s}{\cdot}015)\times +0{\cdot}558 = -\;{\cdot}007 \end{array}\Bigg\}\ \text{sum} = -0^{s}{\cdot}009$$

As the correction for clock error has the opposite sign from that of the time of transit, we have:

$$\Delta t = +0^{s}{\cdot}009.$$

Thus the complete corrections due to errors in the adopted instrumental corrections produced by pivot error are:

$$\begin{aligned} \Delta c &= -0^{s}{\cdot}002 \\ \Delta l &= -0{\cdot}002 \\ \Delta a &= -0{\cdot}015 \\ \Delta t &= +0{\cdot}009 \end{aligned}$$

And the corrections applicable to the right ascensions of the catalogues are:

$$\begin{array}{ll} \{-0^{s}{\cdot}015+\text{Col. II. (Arg. N.P.D.)}\} & \times\,\text{azimuth factor} \\ +\{-0{\cdot}002+\text{Col. I. (Arg. N.P.D.)}\ \} & \times\,\text{level factor} \\ +\{-0{\cdot}002 \qquad\qquad\qquad\qquad\qquad\ \ \} & \times\,\text{collimation factor} \\ +\quad 0{\cdot}009 & \end{array}$$

The corresponding quantities are given in the following table:

Corrections on account of Pivot Errors.

N.P.D.	Collimation.	Level.	Azimuth.	Clock correction.	Catalogue Place.
°	s	s	s	s	s
35	−0·003	0·000	−0·024	+0·009	−0·018
40	− ·003	− ·002	− ·023	...	−0·019
45	− ·003	− ·004	− ·028	...	− ·026
50	− ·003	− ·004	− ·025	...	− ·023
55	− ·002	− ·006	− ·025	...	− ·024
60	− ·002	− ·005	− ·025	...	− ·023
65	− ·002	− ·007	− ·019	...	− ·019
70	− ·002	− ·010	− ·013	...	− ·016
75	− ·002	− ·007	− ·013	...	− ·013
80	− ·002	− ·004	− ·009	...	− ·006
85	− ·002	− ·002	− ·007	...	− ·002
90	− ·002	+ ·001	− ·007	...	+ ·001
95	− ·002	+ ·001	− ·007	...	+ ·001
100	− ·002	+ ·004	− ·006	...	+ ·005
105	− ·002	+ ·009	− ·005	...	+ ·011
110	− ·002	+ ·015	− ·005	...	+ ·017
115	− ·002	+ ·019	− ·004	...	+ ·022
120	− ·002	+ ·021	− ·002	...	+ ·026
125	− ·002	+ ·015	+ ·001	...	+ ·023
130	− ·003	+ ·013	+ ·003	...	+ ·022
135	− ·003	+ ·010	+ ·007	...	+ ·023
140	− ·003	+ ·006	+ ·009	...	+ ·021
145	− ·003	·000	+ ·013	...	+ ·019
150	− ·004	+ ·007	+ ·014	...	+ ·026
155	− ·005	− ·012	+ ·023	...	+ ·015
160	− ·006	− ·021	+ ·038	...	+ ·020
165	− ·008	− ·049	+ ·053	...	+ ·005
170	− ·012	− ·060	+ ·083	...	+ ·020
175	− ·023	− ·130	+ ·125	...	− ·019
180	−	...	...	...	·000
S.P. 180	...	...	...	...	·000
175	+ ·023	+ ·078	− ·070	...	+ ·040
170	+ ·012	+ ·016	− ·047	...	− ·010
165	+ ·008	·000	− ·033	...	− ·016
160	+ ·006	− ·003	− ·017	...	− ·005

Small as these corrections are, there can be no doubt as to their reality. They show that, relative to stars near the equator,

Right Ascensions of stars observed with the Cape Transit Circle towards the Northern Horizon require a small negative correction.

This is exactly the opposite result which is derived from a comparison with other catalogues. This discordance may be due to change in the collimation of the Transit Instrument at different altitudes, and which cannot be eliminated in a non-reversible instrument, or it may arise from lateral refraction produced by the non-symmetrical arrangement of the building outside the shutter-opening.

Both these possible sources of error will be eliminated in the construction and installation of the new Transit Circle.

Note on Dr. Gill's Paper, "On a New Instrument for Measuring Astrophotographic Plates" (Monthly Notices, lix. p. 61). By H. H. Turner, M.A., F.R.S., Savilian Professor.

In the last number of the *Monthly Notices* Dr. Gill describes a new instrument, constructed by Messrs. Repsold, for measuring photographic plates, which he considers an improvement on the instruments in use at Greenwich and at Oxford.* The main features of the Greenwich and Oxford instruments are :—

(1) Rectangular coordinates of the stars on the plate are obtained by referring each star image to the four réseau lines immediately surrounding it.

(2) The x and y coordinates of an image and the size of its disc are measured at the same time. [In some other instruments only one coordinate is accurately measured at one time; the plate is then rotated through 90°, and the other coordinate is measured. There are risks of mal-identification with this method, and it takes a longer time.]

(3) The coordinates are measured by means of *scales* in the eyepiece of the microscope, reading to 0·05 mm., and by estimation to 0·005 mm.

(4) It may be added, as a matter of detail, but a thoroughly important one, that the plate is measured twice in reversed positions (turned through 180°), which determines or eliminates personality in measurement and is a valuable check on mistakes.

Dr. Gill proposes no change in (1), (2), and (4), but substitutes for the scales mentioned in (3) two micrometer screws at right angles. He claims that such screws give a much greater accuracy in pointing on the star images, and I will concede him this point, which amounts to admitting that the *accidental error* of a pointing is diminished about one-half. But consider at what a cost this advantage is obtained!

* For description of the Oxford instrument see *Monthly Notices*, lv. p. 102.

(a) The Introduction of Systematic Errors due to Wear of Screws.

Immediately following Dr. Gill's paper on the new instrument there is another from his own pen on the wear of the micrometer screws of the Cape Transit Circle during ten years. From his annual reports I find that during those ten years about 50,000 observations were made with these screws, and they have worn so as to exhibit errors amounting to about 0″·3. The screws which he proposes to use in his new measuring instrument have precisely the same* work to do as those which read the microscopes of a transit circle, viz., to travel backwards and forwards to a point arbitrarily placed on a space of 5′; and hence we may expect similar wear after 50,000 bisections have been made with them. But to measure his plates for the Astrographic Chart, Dr. Gill's screws will have to make ten or a dozen times this number of observations! At this Observatory during the last year alone 155,000 measures have been made, and if we had used screws they would have had three times the wear of Dr. Gill's transit circle screws; whereas our scales are untouched by wear. If they have systematic errors, these have presumably remained the same throughout, and can be determined by the observations themselves, and then the corrections applied throughout, if thought advisable. But screws would have been gradually wearing all the time, and if the errors at the end of the year were measured some hypothesis would have to be made for applying the troublesome correction depending on the time.

(b) The Introduction of Casual Errors due to Curvature of the Plate.

The use of scales in the eyepiece allows of the "error of runs" being checked at each observation. Dr. Gill adjusts the "runs" (*i.e.* the correspondence of ten revolutions of the screw to one réseau interval), once for all, for any given plate. He says (p. 66):—

"By means of these two screws it is very easy to adjust the micrometer so that the images of the sides of réseau square fit systematically between the parallel webs of the fixed square. This adjustment once made is not liable to change, but on account of shrinkage of the film and division error of the réseau it is never found that all the images of the réseau-squares of any plate exactly fit the fixed square."

"Shrinkage of the film and division error of the réseau" are not, however, the only or (I believe) the chief sources of variation. There is also curvature of the plate, for the plates are by no means flat; and an error due to this cause, while it can be

* There are ten revolutions to the 5′ space for the new instrument, instead of five revolutions, as in the transit circle. But I do not think this will make any difference. On the one hand, the value of a given fraction of a revolution in arc is just halved; but the number of turns to cover any given space, *i.e.* the wearing effect, is just doubled.

promptly corrected when a scale is used, remains uncorrected by Dr. Gill's method, if I understand it rightly. (On this point see also *Monthly Notices*, lv. p. 104.)

(c) The Large Amount of Preliminary Adjustment required.

This can be seen by reading Dr. Gill's paper. With the scales there is practically none. It does not even matter if the scales are oblique to the réseau lines; though it would introduce serious systematic errors if the webs moved by the screws were oblique, and the setting of these accurately involves time and labour. Any accidental breakage, &c., necessitates the repetition of much labour.

(d) The Great Expense of the Instrument.

In some respects this is an unimportant matter; the capital outlay is, in any case, small compared with the total cost of the work to be done. But an expensive instrument cannot, for instance, be ordered in wholesale quantities. We have found it an immense convenience here to have four instruments (total cost £120), one or more of which may be taken home on special occasions, or lent to a measurer who had spare time but could not attend at the observatory, or lent for experiment to other observatories.

(e) Convenience of the Observer.

A scale in the eyepiece is read without removing the eye, so that no change of focus is necessary. To read the graduations of a micrometer screw, on the other hand, the head must be withdrawn; and there is a tendency to withdraw it as little as possible, slightly altering the focus of the eye at the same time. This is a comparatively tiring operation. I notice that Dr. Gill's measurer changes places with the recorder every quarter of an hour or so, which seems to support the view that the operation is a little fatiguing. Here a measurer can go on for two, three, or four hours without sensible fatigue over and above that which any continuous occupation necessarily brings. He also records his own measures. For this he has to withdraw the eye from the microscope, but the record-sheet is easily placed, after a little trial, in such a position that his eye does not change focus.

On actual rapidity it is dangerous to lay too much stress. In this I quite agree with Dr. Gill. But I have been myself astonished to find what can be done with the Oxford micrometers —150 to 180 stars an hour (which would correspond to 300 to 350 for two people working together), and this kept up for four hours! It was only recently that I found out what could be done in this way: my bargain with the measurers was that they should account for fifty stars an hour when we took stock of the week's work every Monday morning; this, I thought, would enable them to do the work well and carefully. The comparison of measures, reverse and direct, was a constant check on the carefulness, of which I found no reason to complain; and yet some of them were measuring at two or three times this rate

when so inclined, enjoying the pleasures of idleness or conversation with the time saved. This frank avowal may cause some amusement, but it may also be of assistance to others in similar [illegible]

(*f*) *Increase of the Numerical Work.*

We limit our work at Oxford to *three decimal places*, *i.e.* our unit is 0″·3, except for the computation of "standard coordinates" from the meridian observations, which has been done to four. [I am not at all sure it would not have been better to work to three only; but the work was arranged before we were bold enough to make this limitation.]

The increase of work involved in going to four places (0″·03) instead of three is enormous; and since the measures are only made to 0″·3, I have not considered it worth while to correct them so elaborately. But if we reduce the probable error of the measures to Dr. Gill's standard, three places is scarcely enough, and this great increase of numerical work is necessary. The increase is not in the ratio of four to three, but in a ratio more like two to one. For instance, in dealing with the differences between measures and calculation, these differences may all be less than ten of the larger units, and expressible therefore by single figures, and it would then take double the number of figures to express them in the smaller units. Consider, too, the difference in labour involved in adding up the columns below :—

	Three Figures.	Four Figures.
$x-x^1$	+·003	+·0028
ax	− 6	− 59
by		+ 04
c	− 23	− 232
	−·026	−·0259

I fear, however, some will regard this economy of figures as false economy. I can only hope it will be given a more extended trial. I do not think those who try it will go back to the older plan of painful accuracy in computation.

To show how little real accuracy is lost by dropping the fourth figure, I give an extract from what we have named the "ledgers," books in which the Cambridge (*Ast. Gesell. Zone Cat.*) meridian places are compared with the Oxford photographic measures on various plates. The results obtained for the same star from different plates—taken at different times and with different centres—are a better test of real accuracy than the accordance of two pointings on the same star image. I have given the results in seconds of arc as a more familiar unit than our unit 0^{R}·001=0″·3. The extract is made quite at random, except that it is taken from a part of the sky where there are many stars.

Corrections to Cambridge Zone Catalogue from Photographic Measures.

Cambridge. Number	Mag.	R.A. 1900·0. h m s	N. Dec. 1900·0 ° ′ ″	Oxford. Corrections. x ″	y ″	Plate Number.	Plate Centre. R.A. h m	N. Dec. °	Date.
11001	8·9	20 8 35·37	27 46 24·7	+1·5	0·0	1105	20 12	27	1897·630
				+1·5	0·0	1113	20 4	27	7·671
				+0·6	+0·3	463	20 6	28	3·695
11002	9·5	20 8 39·39	25 26 40·3	+1·8	−0·9	867	20 12	25	1895·745
				+1·8	−0·9	126	20 8	26	2·613
				+1·5	−0·3	1121	20 8	26	7·690
11003	9·5	20 8 38·67	29 15 51·2	not yet measured					
11004	8·9	20 8 46·50	29 59 36·5	not yet measured					
11005	7·9	20 8 48·78	26 59 0·3	+1·5	0·0	126	20 8	26	1892·613
				+1·2	0·0	1105	20 12	27	7·630
				+1·8	0·0	1113	20 4	27	7·671
				+2·4	+0·3	463	20 6	28	3·695
				+1·2	+0·3	1121	20 8	[illegible]	7·690
11006	9·5	20 8 50·36	28 54 27·0	0·0	+1·8	463	20 6	[illegible]	1893·695
11007	9·5	20 8 52·17	29 17 50·3	not yet measured					
11008	9·3	20 8 57·02	25 14 39·2	−1·5	+0·3	867	20 12	25	1895·745
				−1·2	+0·6	126	20 8	26	2·613
				−1·5	+0·6	1121	20 8	26	7·690
11009	9·2	20 8 58·16	29 5 4·9	not yet measured					
11010	8·8	20 9 1·73	25 13 13·7	+0·6	−0·9	867	20 12	25	1895·745
				0·0	−0·3	126	20 8	26	2·613
				0·0	−0·6	1121	20 8	26	7·690

Results such as these show that the places obtained are sufficiently accurate; while the addition of another decimal place to the residuals, in the case of No. 11005, for instance, is clearly of no interest. Far better spend the time needed to obtain it in taking and measuring another plate.

A Suggestion for the Explanation of Stationary Radiant Points of Meteors. By H. H. Turner, M.A., F.R.S., Savilian Professor.

1. For many years past Mr. W. F. Denning has insisted that there are radiant points of meteors which remain fixed in the same portion of the sky for several months together. Indeed, he is disposed to believe that the Earth is liable to receive showers from the same radiant at all points of her annual orbit. It has been found difficult to explain this phenomenon theoretically. The conception of a swarm of meteors sufficiently extended to cross the Earth's orbit at many points is not difficult; but, if we assume them to be moving in parallel paths, the radiant, which depends on the relative motion of the swarm *and the Earth*, will shift among the stars during the year, as in the case of the well-known August *Perseids*. It would only remain approximately constant in position if the velocity of the meteors were enormously great compared with that of the Earth, a supposition which will not accord with the direct observations of velocity. Indeed, to quote the words* of Professor C. A. Young:—

"No satisfactory explanation of such fixity (of the radiant) as yet appears; and though Mr. Denning is perfectly confident of the genuineness of his discovery, and though it is very generally accepted as a fact, some very high authorities, Tisserand for instance, still question it, as being 'incredible and unaccountable.'"

2. My attention was drawn to this discrepancy between theory and observation more or less by accident. I know nothing of meteoric observation at first hand, but the confidence with which Mr. Denning speaks of the evidence in favour of stationary radiants seems to me sufficient to inspire others with similar confidence, and I devoted some little time to thinking over the matter. I was ultimately led to consider the effect of the Earth's action on that portion of the swarm which passed near, but did not meet, the Earth. Schiaparelli and others have fully considered the effect of the Earth's attraction in deflecting the paths of meteors which reach our atmosphere and become visible to us; but, so far as I have been able to ascertain, no one has yet considered fully the effect on the rest of the swarm. A brief note on the subject which I submitted to Professor Alexander Herschel received such favourable comment from him that I am encouraged to publish it. The original note was rather hurriedly drawn up, and is not reproduced verbatim, but is given in a revised form in the next five paragraphs.

3. Suppose, in the first instance, that a stream of meteors is

* Young's *General Astronomy*, edition of 1898, p. 481.

approaching the Earth at rest, and that there is no other disturbing body. Some of them, following paths C D E (fig. 1), will

FIG. 1.

meet the Earth, or its atmosphere, and be stopped; but others, further away, will follow paths such as A *a*, B *b* or F *f*, G *g*, which are hyperbolas of large eccentricity, if the original velocity of the meteors is such as occurs in nature.

4. The total effect of the Earth's attraction on any meteor path B *b* may be estimated by comparing the motions at two points, B and *b*, so far removed from the Earth on opposite sides that the Earth's attraction is very small. At these points the path is practically straight, and the velocity is the original velocity of the meteor stream. Between B and *b* the velocity gradually increases to a maximum at perigee, and then gradually decreases again to its old value, at the same time changing continually in direction. The change in direction will not be large if the original velocity of the meteors is such as is usually observed, *i.e.* comparable with that due to the Sun's attraction from infinity.

[For if V be the original velocity, and v the velocity at any point distant r from the Earth's centre, we have

$$v^2 = V^2 + \frac{2m}{r},$$

where m is the mass of the Earth.

M 2

Also

$$V^2 \text{ is comparable with } \frac{2M}{R},$$

where M is the Sun's mass and R the distance of Earth from Sun. Thus the fractional increase in v^2 due to the Earth's action is of the order

$$\frac{2m}{r} \bigg/ \frac{2M}{R}, \text{ or } \frac{m}{M} \cdot \frac{R}{r}.$$

The smallest value of r is 4,000 miles, when the meteor just grazes the Earth's surface. Hence the greatest increment in v^2 is about

$$\frac{1}{330000} \times \frac{93000000}{4000} = \cdot 07 \text{ of the whole.}]$$

Nor will the change in magnitude be very great under the same circumstances. But it is to be noted that there is an accumulative effect on the *time* from B to *b*. At every intermediate point between B and *b* the velocity is greater than it would have been had the Earth not existed, and *the time between* B *and b is shortened* in consequence. It is this effect on which I wish to lay stress. It is the same for meteors on both sides of the Earth, such as B *b* and F *f*, whereas the change of direction is in opposite senses in these two cases. Thus if the same meteor could pass on one occasion to the left of the Earth, as along B *b*, and on a second occasion to the right, as along F *f*, the two changes of direction would annul each other, but the time-gains would add together.

Thus we may sum up the total action of the Earth as follows: –

(*a*) The velocity of a meteor after the encounter is unchanged in *magnitude*.

(*b*) The velocity after a single encounter is changed slightly in direction, but after two encounters in which the meteor passes on opposite sides of the Earth this change of direction may be annulled.

(*c*) But the *time of passing the Earth is shortened*: by which is meant the whole time spent between two points B and *b* at the limit of the Earth's sphere of influence.

5. Now consider the Earth in motion round the Sun as usual, and a meteor swarm about to cross its path. The swarm has

(A) the velocity of the Earth.

(B) the relative velocity of swarm to Earth.

Reverse for both bodies the velocity of the Earth, and during the subsequent motion reverse on both the effect of the Sun's acceleration on the Earth.

Then the motion of the swarm relatively to the Earth is given by supposing it to move with initial velocity (B) under accelerations due to

(C) the attraction of the Earth.

(D) the *difference* of attractions of Sun on Earth and swarm, the familiar "disturbing force" of the Sun. Now, in Lunar Theory this disturbing force is shown to be small compared with the Earth's direct action at 240,000 miles distance. Thus at distances comparable with the Earth's radius of 4,000 miles it may be neglected entirely.

6. Hence for the study of the relative motion of swarm to Earth, we may regard the swarm as approaching a stationary Earth with the relative velocity (B) under (C) the Earth's attraction only. This is just the case considered in §3 and §4; and we may therefore apply the conclusions therein arrived at. In applying them it is to be remarked that there is no difficulty in imagining how the change of direction may be annulled as in (*b*) of § 4. For in the case of a swarm moving in an orbit the period of which is not commensurable with that of the Earth, any single meteor would pass at successive returns through the Earth's orbit in all positions relatively to the Earth indifferently—before or behind, near or far; and the average change of direction

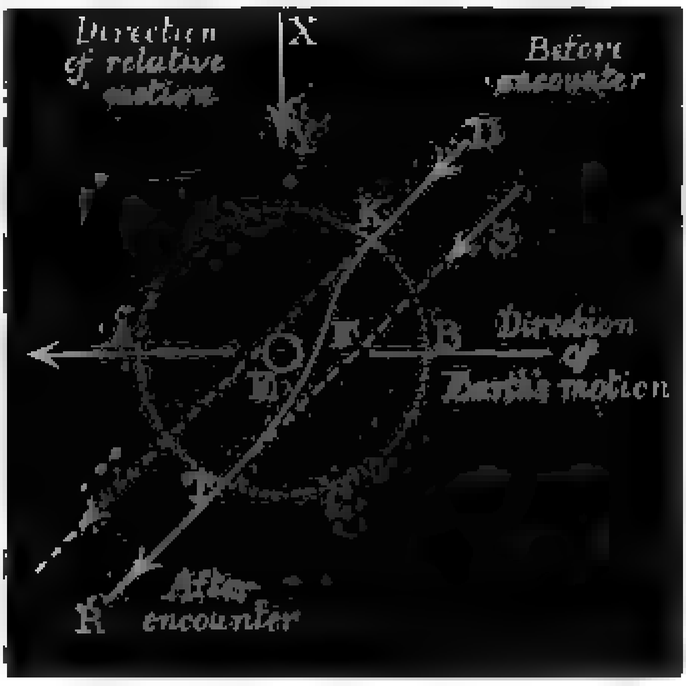


Fig. 2.
Average effect of Earth's attraction on motion of a meteor.

would be zero. Thus we may state the effect of the Earth's action on the motion of a meteor, on the average of a series of encounters in which the meteor escapes being actually stopped by the Earth, as follows :—

(*d*) The *relative velocity* is the same in *magnitude* after the encounters as before.

(*e*) The *relative velocity* is also the same in *direction* after the series of encounters as before.

(*f*) But on each occasion the meteors have crossed the Earth's

orbit a little earlier than they would have done had the Earth not attracted them.

7. The average effect of the Earth's attraction on the motion in space is shown in fig. 2 (much exaggerated). Before the encounter the meteor's path is along D K; and if the Earth had no attraction it would move with uniform velocity along the dotted line. It would appear to the Earth to come in a direction X Y, say.

Owing to the attraction of the Earth, which begins to be felt about K, the relative velocity in the direction X Y is increased, the orbital velocity common to Earth and meteor in the direction B A remaining the same. Hence the velocity of the meteor in space takes a direction more inclined to B A and it follows the curved path D K F T R, which only resumes its original direction at T R, when the increase of velocity has been destroyed and the Earth's attraction is again insensible. At the next return of the meteor it will arrive in the path S T R, which crosses the Earth's orbit a little sooner than the former; but it will approach the Earth with the same relative velocity both in *magnitude and direction* (on the average of several encounters) as at first. Since the position of the radiant depends simply on the relative velocity of meteor and Earth, the position of the radiant will be unaltered at the return, but meteors will be noted coming from it a little earlier than before. At the same time the Earth will only draw back in this way a few meteors of the swarm, while others will be left practically undisturbed. So that the Earth has a tendency to spread the meteor orbits along its orbit, the radiant remaining the same, but the time of the shower being gradually protracted. So far this action of the Earth seems promising as a *vera causa* for the existence of "stationary radiants."

8. But there are two important difficulties in extending this principle. The first is that if the action is slow (and the numerical computations which follow show how slow it is) it will have time to affect all the members of the swarm equally; and thus, instead of a spreading of the swarm round the Earth's orbit, we shall merely have a progressive motion of the node for the whole swarm. To get a spreading action we must show cause why certain members of the swarm may be affected more than others; and not only *more*, but *much more*, so that for some the node moves a considerable arc, while for others it stands still. If the meteors are all moving in precisely similar parallel paths it is not easy to see how this selective action is to take place. But is this a correct picture of the motion of a meteor swarm? To keep the swarm extended must there not be some motion of rotation round an axis, as in the case of all other bodies of the solar system? The total mass of the swarm being presumably small, a comparatively slight rotation would keep it extended, so that in considering the resultant velocity of any single meteor in space, due to its motion round the Sun and its rotation round the axis of the swarm, the latter may be neglected. But a rotation, however

slight, would be important from our point of view for the following reason.

The axis of rotation might be inclined at any angle to the direction of motion; and the rotation could thus be resolved into components, one of which is about an axis coinciding with the direction of motion, the period being generally incommensurable with the time of orbital revolution. The effect of this component will be to transfer any particular meteor from one side of the centre to the other in an arbitrary manner; so that if the period of revolution of the swarm round the Sun were an exact number of years, the Earth's attraction might still cause no *deflection* of the path on the average. Thus suppose A B to be a portion of the Earth's orbit, C the position of

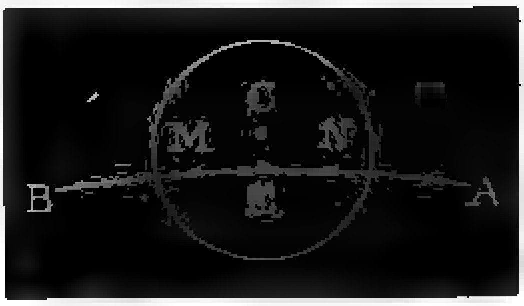


Fig. 3.

the centre of the swarm when the Earth is at E. After an exact number of years, E returns to E and C to C; and if there were no rotation of the swarm, any particular meteor M would return to M. It would thus always pass the Earth on the same side, and not only the motion of the node would be multiplied at each return, but also the *deflection of the path.* But if there is any rotation, however slow, about the axis C E, then the meteor M may at the next return be at N, or any intermediate position; and so long as the time of rotation is incommensurable with that of revolution, the meteor will occupy in turn all positions in the circle described by M, half of which are to the right and half to the left of the Earth, so that the accumulated deflection due to the Earth's attraction is zero.

Thus, if the swarm rotates, we can have the phenomena of stationary radiation developing, even if the period of revolution of the swarm round the Sun is an exact number of years.

We can now explain the spreading of the swarm.

Let us suppose the original period $n+x$ years, where n is an integer and x an incommensurable fraction. The attraction of the Earth causes a motion of the node as above described: possibly common to the whole swarm—no scattering, all members of the swarm are in time equally affected. But the period slowly alters; since the *relative* velocity (to the Earth) remains the same, the velocity in space changes, and hence the period will change, either increasing or diminishing. It will thus gradually approach

either n or $n+1$ years, *i.e.* it will approach commensurability. When the period becomes an exact number of years, some particular meteors will always pass very close to the Earth at every return, and the node of these will be moved rapidly. Others will be persistently avoided by the Earth, so to speak, and the node will remain unchanged. Hence the swarm will be split up. Again, for the portion which moves onward the period will gradually become incommensurable, and thus the action slower; but it will nevertheless proceed, and will carry the node round, further altering the period until it is again commensurable (in $n-1$ or $n+2$ years), when a portion of this portion will again be detached, and so on. The disintegrating action thus takes place more or less in steps, though there is no actual discontinuity. Of course, there are minor steps when x becomes not ± 1, ± 2, ± 3, &c., but $\pm\frac{1}{2}$, $\pm\frac{1}{3}$, &c.

9. The second difficulty is more important. According to the principle under consideration the relative velocity of the meteors to the Earth remains unchanged, not only in direction (on the average), but also in magnitude. Now, I gather that this does not accord with observation. Meteors which *meet* the Earth in its orbit are observed to be swift, and those which *catch it up* are slow; and this, I am told, is the case for meteors belonging to the same stationary radiant. We have thus proved too much, if anything. We want the relative velocity to remain constant in direction, but *not in magnitude*. This is a formidable obstacle to the application of the above principle, and at present I do not see the way to surmount it. For diminishing the magnitude of a velocity without altering its direction, a resisting medium seems a likely agent; and if there is a resisting medium, small bodies like meteors should be specially susceptible to its influence. Now, if we had only the meteors near the apex and anti-apex to consider, an explanation of the swift velocities near the apex, and the slow near the anti-apex, might be offered as follows:—

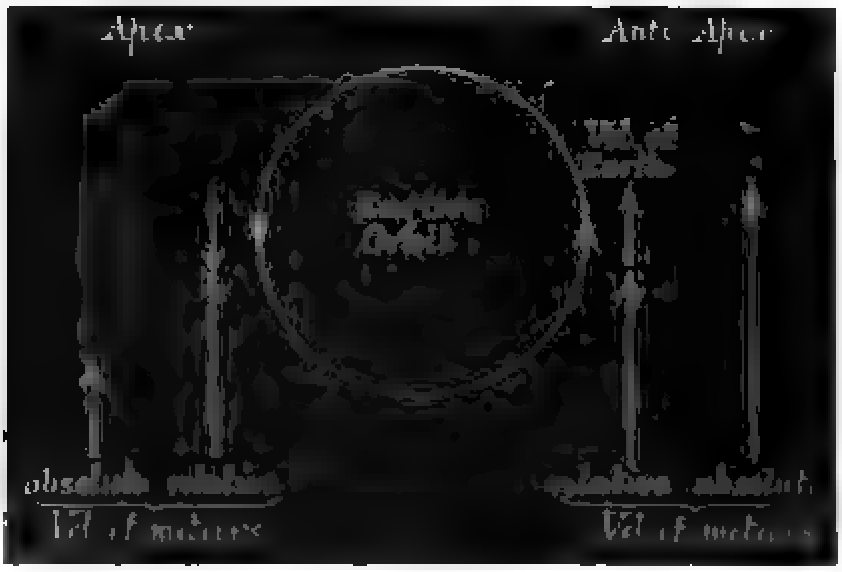


Fig. 4.

Suppose, first, that the meteors had been scattered round the Earth's orbit as above indicated, the relative velocity being constant both in direction *and magnitude.* Then at the apex the velocity of the meteors in space is the difference of the relative velocity and that of the Earth, and is small; at the anti-apex it is the sum of these velocities, and is large. Hence the latter would be reduced by a resisting medium fixed in space much more than the former: so that the relative velocity would become smaller at the anti-apex than at the apex.

But at intermediate points the relative velocity would be changed not only in magnitude, but in direction, by such a diminution of the absolute velocity. This explanation breaks down.

10. In spite of this difficulty, I venture to publish this suggestion, in the hope that it may perhaps at least draw attention to the important problem of stationary radiants. I am well aware that some experienced meteor-observers deny their existence altogether, alleging, for instance, that Mr. Denning has obtained his results by confusing together meteors belonging to different swarms, straining observations, &c. My own opinion is that this interpretation of Mr. Denning's observations is impossible, and that we are face to face with another of those cases in which observation supplies us with facts apparently inexplicable by theory at present, for which a theoretical explanation will yet be found. It is therefore a question merely of attracting sufficient attention to the matter; and the object of this note will have been attained if it succeeds in attracting a little more attention from mathematicians to the present discrepancy between observation and theory. In this course I am glad to think that I have the approval of Mr. Denning, and of Prof. A. S. Herschel, who has kindly added in commentary a paper of his own.

11. The foregoing sketch of the Earth's action would be incomplete without some rough numerical estimate of its amount, which will now be attempted.

12. Let us first examine for what distance a meteor may be regarded as travelling under the Earth's attraction only. This will depend on the velocity of approach. Meteors which are seen in our atmosphere have parabolic or nearly parabolic velocities: that is, the periods of revolution round the Sun must be several years at least. We may, of course, disregard those with velocities greater than parabolic: for they will not return, and we are considering periodic swarms. Thus we may consider the maximum velocity of a meteor in space when it meets the Earth's orbit to be V, where

$$V^2 = 2M/R,$$

M being the Sun's mass and R the radius of the Earth's orbit. Since it may approach the Earth at the apex, its maximum *relative* velocity is $V+W$, where W is the velocity of the Earth, *i.e.*

$$W^2 = M/R.$$

Thus

$$(V+W)^2 = (\sqrt{2}+1)^2 M/R$$
$$= 5{\cdot}8\ M/R;$$

while at the apex the relative velocity would be V − W, where

$$(V-W)^2 = (\sqrt{2}-1)^2 M/R$$
$$= {\cdot}17 M/R.$$

As a typical case we shall consider the relative velocity to be V; the other cases can easily be considered afterwards.

Let r be the distance of the meteor from the Earth, mass m. The "disturbing force" of the Sun, *i.e.* the difference between attractions of Sun on meteors and Earth is of the order

$$M\,.\,r/R^3,$$

while the direct attraction of the Earth is of the order m/r^2. These two become equal when

$$(r/R)^3 = m/M = 1/330{,}000,$$

or

$$r = R/70 = 1{,}300{,}000 \text{ miles}.$$

At half this distance the disturbing force (which varies as r^3 compared with Earth's action) has only $\frac{1}{8}$ the effect. Hence we may consider the meteors as moving under Earth's attraction only for about 500,000 miles on each side of the Earth's orbit, but not more.

With velocity V, which is 1·4 times the Earth's velocity of 1,500,000 miles per day, they would take about 12 hours to describe this double-space. With velocity V + W it would be about 3 hours; with velocity V − W, about 3 days.

13. In § 4 it is shown that the increase of velocity due to the Earth's action is very small. Let us further calculate the minimum eccentricity of the hyperbola described relatively to the Earth. If a be the major axis, e the eccentricity, v the velocity at distance r from the Earth,

$$v^2 = m\left(\frac{2}{r} + \frac{1}{a}\right);$$

and when r is infinite

$$v^2 = V^2 = 2M/R.$$

Thus

$$m/a = 2M/R,$$

or

$$a = 141 \text{ miles}.$$

Now the minimum perigee distance is 4,000 miles; thus

$$a(e-1) > 4000$$
$$\therefore e - 1 > 4000/141,$$

or

$$e > 30.$$

If instead of V we took V − W, we should obtain

$$a = 1{,}700 \text{ miles},$$
$$e > 3{\cdot}3.$$

The perigee distance will, of course, always exceed 4,000 miles, so that e and also $(e-1)$ will generally be large quantities, and we may write $e-1=1/f$ where f is small, and only first powers of f need be retained.

14. To calculate the total time-gain due to the Earth's attraction, let us suppose that the path of a meteor is *constrained to be a straight line*, which makes the integration a little simpler, while clearly not seriously affecting the result.

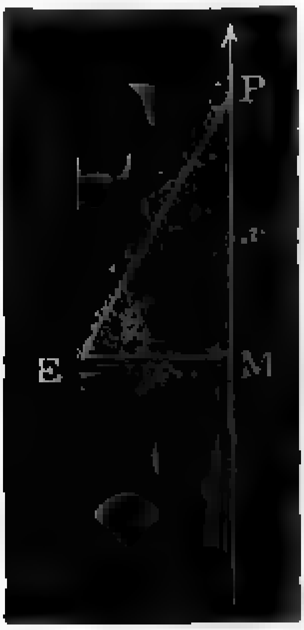


FIG. 5.

Let a be the perigee distance EM (fig. 5), and let MP$=x$, MEP$=\theta$, where P is the position of the meteor at time t; so that

$$x = a \tan \theta.$$

The equation of motion is

$$\frac{d^2x}{dt^2} = -\frac{m}{x^2} \sin \theta.$$

or

$$\frac{dx}{dt} \cdot \frac{d^2x}{dt^2} = -\frac{m}{a} \sin \theta \cdot \frac{d\theta}{dt}$$

$$\therefore \left(\frac{dx}{dt}\right)^2 = C + \frac{2m}{a} \cdot \cos \theta.$$

When $\theta = \frac{\pi}{2}$,

$$\left(\frac{ds}{dt}\right)^2 = V^2 = \frac{m}{a} = \frac{m}{a}(e-1) = \frac{m}{af}.$$

$$\therefore\ a \sec^2\theta \frac{d\theta}{dt} = \frac{dx}{dt} = V(1 + 2f\cos\theta)^{\frac{1}{2}},$$

$$\therefore\ V\,dt = a\sec^2\theta\,.\,(1 - f\cos\theta)\,d\theta,$$

or

$$Vt = a\left[\tan\theta - f\log_e \tan\left(\frac{\pi}{4} + \frac{\theta}{2}\right)\right],$$

no constant being required if θ and t vanish together.

Now if the portion of the path under consideration commence and end at a distance of 500,000 miles from the Earth, perigee distance being 4,000 miles, the values of tan θ at the limits are ± 125, and of θ are $\pm 89°\ 33'$

$$\log_e \tan\left(\frac{\pi}{4} + \frac{\theta}{2}\right) = \pm 5{\cdot}5.$$

Thus in

$$t = \frac{a}{V}\left[\tan\theta - f\log_e \tan\left(\frac{\pi}{4} + \frac{\theta}{2}\right)\right],$$

where the first term clearly corresponds to the uniform (undisturbed) motion in a straight line, and the second to the effect of the Earth's attraction, the ratio of the second term to the first is

$$f \times 5{\cdot}5/125;$$

or if $f = 1/30$, the ratio is $1/700$ say. Thus, if the undisturbed time be twelve hours (see § 12) the time gain is about *one minute*. Near the apex, where the relative velocity is $V - W$, f is much larger and also the time within which we integrate is larger; and thus the time-gain would for both reasons be larger. The time-gain in the case where the meteor just misses the Earth is in fact represented approximately by

$$f\,.\,T/23,$$

where T is the time spent within the sphere of influence of the Earth. Thus at the apex, where T = 3 days (see § 12) and $f = 1/3{\cdot}3$, we have for the time-gain about one hour instead of one minute; at the anti-apex, on the other hand, the minute becomes a few seconds only.

15. But so long as the effect is shown to be sensible, it is not a fatal objection that its action would take a long time to develop. There is no reason that I know of why the swarm should not have been subjected to the Earth's attraction at successive returns for, say, 1,000,000 years. If n years be the period of commensurability (as suggested in § 8) for some portion of the swarm, and this portion be moved one minute at each return,

then in 525,600 n years the node for this portion would be moved completely round the Earth's orbit. For a smaller spreading smaller figures would be necessary.

16. In such an important matter it is of course eminently desirable to undertake a more elaborate investigation, and this I shall hope to do. Meanwhile these notes may at least, as suggested in § 10, have the desired effect of attracting attention to an interesting problem.

Observations of the Leonids at Perth Observatory, Western Australia. By W. E. Cooke.

A search was made for these at the Perth Observatory, W.A., on November 13 and 14. We confined our observations to counting the number seen in a particular region of the sky during each successive 15 minutes.

On the first night I took a circle of 10° radius round *Aldebaran*, and Mr. Yeates took the same-sized region round *ζ Leonis*. The night was brilliantly clear.

On the 14th Mr. Yeates took the same region as before. Mr. Curlewis took *Albebaran*, and I took an irregularly shaped region visible through the shutter opening of the Dome, between *Sirius* and *Procyon*. My observations were slightly interrupted at times, as I had strapped a small camera on the astrographic mounting, and had to attend to this occasionally. The sky was generally clear, but some very thin stratus cloud drifted across from time to time.

The photographs produced no results of any value.

Results.

1898, November 13.

Observer	Region round	From 6.15 to 6.30	6.30 6.45	6.45 7.0	7.0 7.15	7.15 7.30	7.30 7.45	7.45 8.0 G.M.T.
Cooke	Aldebaran	...	...	...	0	1	0	0
Yeates	ζ Leonis	...	...	..	1	0	2	1
			November 14.					
Cooke	Sirius to Procyon	0	0	0	0	0	0	0
Curlewis	Aldebaran	0	2	1	1*	2	2†	3
Yeates	ζ Leonis	1	2	1	5	0	3	0

Perth Observatory, W.A.,
1898, *November* 16.

* A brilliant one, straight through *Aldebaran* from the direction of *ζ Tauri*.

† A very brilliant one, just below *Aldebaran*, parallel to above, leaving luminous trail after disappearance.

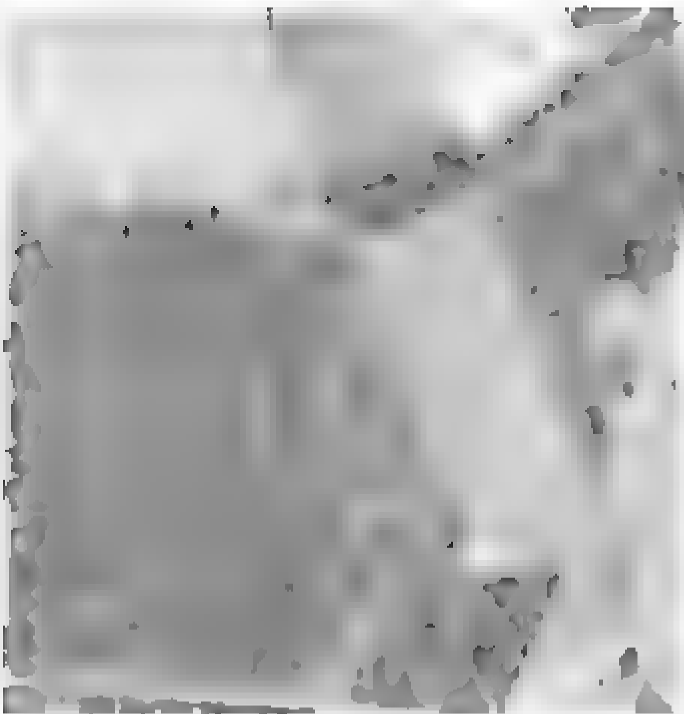
Preliminary Description of the New Photographic Equatorial of the Cambridge Observatory. By Sir Robert Ball, Director of the Observatory.

There has recently been added to the equipment of the Cambridge Observatory a photographic equatorial of novel design, which is so bold a departure from the ordinary forms that it seems well to give a prompt preliminary description of it pending the appearance of a detailed description in the publications of the Observatory.

The essential features of the plan were proposed so long ago as 1884 by Sir Howard Grubb in a paper in the *Phil. Trans. R. Dubl. Soc.* (vol. iii. series 2, p. 61). The instrument is a *coudé* telescope, but of a different type from the *Équatorial Coudé* of M. Lœwy. A long and heavy tube is mounted on bearings top and bottom, so that its axis of rotation is the polar axis of the instrument. Towards its lower end is carried the declination axis, and upon this axis turns a short tube carrying the object-glass. Upon an axis concentric with the declination axis is carried a plane mirror, which is geared so as always to bisect the angle between polar axis and objective tube. If, then, the objective tube is directed to any star, the convergent beam from the object-glass is received by the plane mirror, reflected up the polar tube, and brought to a focus at the upper end of the tube. The observer remains in a fixed position, looking down the polar tube from the top. If, then, the polar tube is carried up into a closed room, while the rest of the instrument is mounted under a cover, which can be moved right away, leaving it in the open air, the observer can work in a closed and comfortably warmed room, and can from it command any part of the sky within range of the instrument without the continual trouble of moving dome and shutters.

This form of *coudé* has the advantage over that of M. Lœwy that only one plane mirror is required instead of two. It has, of course, on the other hand, the disadvantage that the regions close to the pole are cut off by the building. It has the advantage over all forms of fixed telescope fed by a heliostat or cœlostat that the angle of incidence on the plane mirror does not alter during the exposure on a given object, though it is different for objects of different declinations.

While the observatory syndicate was discussing the question of building a photographic equatorial a letter was received from Professor Turner and Dr. Common bringing to their notice the advantages of this new form of equatorial, and urging them not to neglect the opportunity, which so rarely presents itself, of building a large instrument upon original lines. This proposal was favourably entertained by the syndicate, and the plans for the new instrument were prepared by Sir Howard Grubb.



[redacted]

The building in which the telescope is installed was designed by Mr. T. D. Atkinson, architect, of Cambridge. The main part of it is of red brick, square, placed with a diagonal in the meridian, with the south corner flattened. To the south of the main building, and adjoining it, a low wall encloses a rectangular floor. Along the top of the wall rails are laid, and are carried forty feet to the south on brick piers. Upon this railway runs a light house, a skeleton of iron covered with papier-mâché.

The upper and lower bearings of the polar axis rest upon very massive concrete piers, the tall one for the upper bearing just inside the flattened south corner of the main building, the short one for the lower bearing near the southern end of the enclosure which is covered by the running house. The piers are carried down through the foundations of the building, separated from them by a sand joint, and rest upon an excellent foundation of hard blue gault clay.

The heavy conical polar axis tube passes through the wall of the main building to its upper bearing upon the tall pier. When the running house is closed its north end makes a weather-tight joint with the building above the point where the polar tube passes through the wall. The instrument is then completely protected from the weather.

The running house is opened and closed by a chain which passes round a winch at the south end of the railway. It runs quite easily, and can be wound away to the end of the railway in about a minute.

On the ground floor of the building is a large photographic dark room. A doorway under the tall arched pier leads into the running house. A staircase leads upstairs to the observing room, whose high pitched roof, covered with lead, is designed to cut off as little sky as possible from the instrument.

In the south corner of the observing room the tall concrete pier comes up to the level of the floor, and is capped by a large block of stone. To this is bolted the large casting which carries the V bearing for the upper end of the polar axis, the driving clock, automatic electric control, and gearing for the driving sector.

With this form of instrument it is, of course, impossible to reach to the pole. The roof of our building begins to cut off light from the object-glass when the instrument is set on the meridian to decl. 75° N. To allow the objective tube to be turned so far north it was necessary to cut away very considerably the polar tube, as the photograph shows. And a correspondingly large piece had to be cut out of the objective tube, which would otherwise have intercepted a portion of the light after reflection from the mirror. This cutting away of the objective tube is undoubtedly a source of weakness. Had we been content to sacrifice all the sky within 30° of the pole, scarcely any cutting away of the objective tube would have been required. As it is, it will be necessary to devise a self-adjusting covering of some flexible material to cover the large opening which is left when the

instrument is turned to the south. We have not, up to the present, arrived at a satisfactory solution of this problem.

The object glass, by Messrs. Cooke & Son, of York, has an aperture of 12½ inches and a focal length of 19·3 feet. It is one of their new triple photo visual combinations (H. D. Taylor's patent).

The objective tube is bolted to a square box which is carried on the declination axis. To the east side of this box is screwed the declination circle; and on the west side is a crown wheel which engages in a pinion on the end of a rod which is carried up to the eye end, and geared to a hand wheel. This provides for the quick motion in declination. Rods which actuate the clamp and slow motion in declination are also carried up to the eye end.

Inside the square declination box is the mirror box, which turns on an axis concentric with the declination axis. At each end of the mirror axis is a large drum, and inside these, on the ends of the declination axis, are similar drums of half the diameter of the outer ones. Flexible steel tapes are carried in opposite directions off the mirror drums, round pulleys, and on to the declination drums. When these tapes are tightened the mirror axis is thus firmly connected with the declination axis, and the mirror is constrained to move in declination at half the rate of the objective tube. If, then, when the objective is turned into the polar tube until their axes coincide, the mirror is set normal to these axes, it will in all positions bisect the angle between the objective and polar tubes. We are indebted for the mirror to the generosity of Dr. Common.

The adoption of a *coudé* form for a photographic telescope involves almost necessarily the adoption of the principle of guiding by a star on the edge of the field, just off the edge of the plate. Dr. Common has also kindly lent us for our instruction and imitation an apparatus which he had made on this principle, and has described in the *Monthly Notices* (vol. xlv. p. 25). The plate-holder and the guiding eyepiece, which can be moved with reference to the plate-holder in one coordinate, are carried upon a double slide, movable in two directions at right angles to one another by two screws with large milled heads. Corrections to the guiding in either coordinate can thus be given without disturbing in any way the driving of the telescope, or making use of the slow motion of the objective tube in declination.

The driving clock and automatic electric control are of Sir Howard Grubb's standard pattern, with the exception of the controlling pendulum, which is not electrically driven, but swings freely.

The hour circle, just above the upper bearing, is read directly by the reading telescope at the eye end; and by means of a system of reflecting prisms and lenses in an elbowed tube, which can be turned into the axis of the same telescope, the declination

circle at the lower end of the polar tube upon the declination axis can be read.

It is impossible to speak at present of the performance of the new instrument. The non-reversibility, the introduction of the mirror, and the impossibility of getting at the pole have led to some difficulties in the adjustment. A description of them must be deferred. But it is, perhaps, allowable to say now that everything seems to promise well for the success of the new form.

For much of the design and for constant assistance at every stage of the work we are indebted to Mr. Newall, and I must also add that Mr. Hinks has given incessant attention to the carrying out of the details of the building and the erection of the instrument.

Note on the Exterior Nebulosities of the Pleiades.
By E. E. Barnard.

These nebulosities, shown on two plates taken by me with the Willard lens in 1893, have been amply verified (if such a verification were at all necessary).

These plates were given exposures of 4 hours and 10½ hours. The nebulosities are shown on both plates, but, of course, best on the longer exposure. (See *Monthly Notices*, lvii. pp. 10–16.)

I have lately seen two other photographs that show these nebulosities distinctly.

The first of these was made with a 6-inch portrait lens by Dr. H. C. Wilson, of Northfield, Minn., with 11 hours' exposure, which shows the nebulosities even more distinctly, in some respects, than they are shown on my plates.

While at Harvard College Observatory this summer I was shown a fine photograph of the *Pleiades* by Professor S. I. Bailey, which was taken by him in 1897 October with an 8-inch doublet at Arequipa with an exposure of 5 hours. This plate shows all these exterior nebulosities better than they are shown on my 4-hour plate, but not so well as with the 10-hour exposure.

It would therefore appear that a failure to show these remarkable features with an ordinary portrait lens and an exposure anything like 4 or 5 hours must be attributed to something else than their non-existence.

Yerkes Observatory, Williams Bay, Wis.:
1898 *October* 22.

Note on Espin's Object in Perseus, R.A. 4^h 26^m. Decl. +51°. By C. D. Perrine.

(*Communicated by Rev. T. E. Espin.*)

I have examined this region on two nights, November 16 and 17, with the 12-inch equatorial, using a power of 85, and with the 6½-inch comet-seeker, using a power of 38. The conditions have been excellent for this work, the atmosphere being unusually transparent, and the seeing good.

I have been unable to see anything unusual about this region; there are fewer stars than in the immediate surroundings, which gives the impression of a darkening. There are some 13th and 14th magnitude stars in the area, however, and a very faint cluster, 3′ or 4′ in diameter, on the southern limit of the area. With a low power the latter has a slightly nebulous appearance. It is similar to other blank fields in the sky, but is not nearly so dark as some of the so-called "coal-sacks." I see no trace of nebulosity.

Lick Observatory: 1898 *November* 17.

The Great Sun-spot of September 1898. By W. H. Robinson.

(*Communicated by the Radcliffe Observer.*)

Two or three interesting features in connection with the appearance of this Sun-spot during its passage over the Sun's limb may be worthy of being placed upon record.

It will be remembered that the spot was the principal one of a group of unusual dimensions, and attracted considerable attention during its period of visibility from September 3 to 15.

Frequent observations, with sketches, were made at this observatory, using the Barclay equatorial. Two of the sketches are here reproduced.

On September 15, at 1.15 p.m., the spot was observed to be very close indeed to the limb, being only separated from it by a bright, uneven line. A sketch was made, and a remark added as follows: "Preceding edge of spot (on limb) brighter than adjacent photosphere." A good opportunity for seeing the phases of the spot in its transit over the limb being thus afforded, it was decided to make further observations later on, and at 3.45 p.m. the telescope was again turned to the object. But, instead of seeing, as expected, an indentation on the edge of the Sun, the spot was visible as a *projection beyond the limb* (see sketch 2). The observer's remark for this time was: "In intervals of good definition this was seen very distinctly, and looked very like a crater on the Moon's terminator with the illuminated side pre-

ceding. Might not this phenomenon be an effect of irradiation? (See note made, concerning brightness of preceding edge of spot, at 1.15 p.m.)"

FIG. 1.
1898 Sept. 15, 1.15 p.m. G.M.T.
Sun-spot near limb.

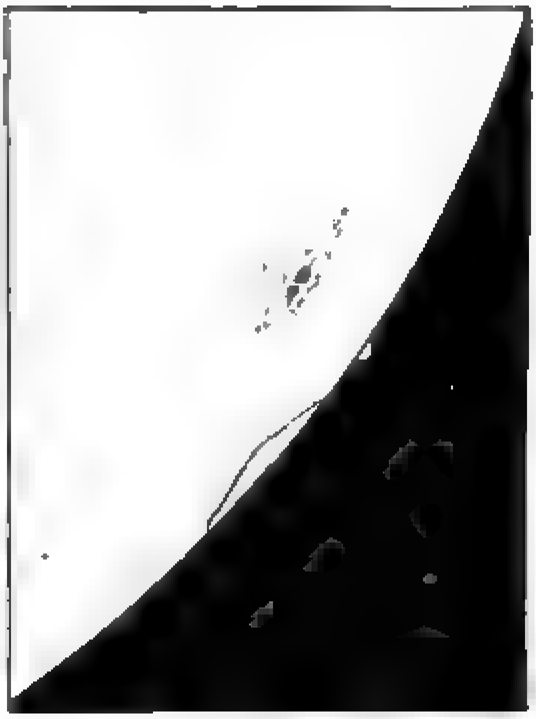


FIG. 2.
1898 Sept. 15, 3.45 p.m. G.M.T.
Showing projection.

[Near the base of the projection a trace of the spot's umbra was occasionally seen just within the solar limb, but this does not appear in fig. 2.]

Observations of faculæ beyond the solar limb are mentioned by Young in his work on "The Sun." He says: "On a few occasions, when a spot of unusual size and depth passes over the limb of the sun, a distinct depression is observed in the outline. . . . Usually, however, the faculæ, which surround the spot, mask this effect entirely, and often actually give us a number of little projecting hillocks in place of the expected depression."

Mr. Maunder, in *The Observatory* for October 1898, states that "the great spot was last seen—as a notch on the west limb—on September 15, and it was then followed only by one spot, the rearward spot of the preceding day." Mr. Newbegin's photographs also show a depression on the limb (*Observatory*, January 1899). The apparent discrepancy between these and the Oxford observations will be explained if the "notch" occurred between 1.15 and 3.45 p.m. At the latter time the projection before described was distinct. It was also intermittently followed until about 5.15 p.m.

The second remarkable feature was that of dark lines which were plainly visible near the limb (see both sketches). At the earlier time, 1.15 p.m., they resembled long furrows with bright edges. The original notes are as follows:—"1.15 p.m. 'Canals' dark, as shown, very distinct, with bright 'banks.'" "3.45 p.m. The longer 'canal' is still visible."

Mr. Dawes (*Monthly Notices R.A.S.* xx. 56) gives an observation of dark lines seen by him on the solar surface. He says: "During the most tranquil moments I satisfactorily made out an excessively narrow *black* line, a little broken in two or three places, as if by irregularities in the inner bright streak." But Dawes' observation was interrupted by a storm of hail, snow, and sleet.

In conclusion, it may be worth mentioning that the Sun-spot roughly indicated in the sketches, and called in a previous quotation "the rearward spot," also attracted notice here on the afternoon of September 15. In intervals of good seeing it was a beautiful object; the most striking feature being its many concentric, and apparently shelving, penumbræ, presenting some very fine detail.

Radcliffe Observatory, Oxford:
1899 January 9.

Note on a Preliminary and Unsuccessful Attempt to Photograph the Corona without an Eclipse. By Rev. C. D. P. Davies, M.A.

Before attempting a spectroscopic plan which I have had in mind with a view to investigate the corona without a total eclipse, it struck me that it might be just worth while to try something much simpler, unpromising though the prospect might be. I have tried it with results which I regard as negative, but which, nevertheless, it may be well to record, if only on the chance of saving others future trouble and disappointment.

In a photograph taken by Mrs. Maunder, after the end of totality in India last January, the whole outline of the Moon was induced to impress its image on the plate in spite of the intrusion of light from the photosphere into the camera. It occurred to me as being just within the bounds of possibility that traces of the corona might be obtained if light direct from the photosphere were prevented from falling on the lens producing the image on the plate. It would thus not enter the camera at all. I am not aware that this has been tried before. It is not quite the same thing as the employment of a screen, bar, or other eclipsing device in an eye-piece.

The following is the arrangement that I adopted: In a wooden tube of square section and four inches internal diameter I placed (*a*) an achromatic object-glass (the "Webster") of two inches diameter and 28-inch focus. In the focus of this, and coincident with the Sun's image, I soldered at the intersection of two fine wires set at right angles to each other (*b*) a brass circular disc of such size as just to cut out the image of the photosphere. The disc and wires supporting it could be rotated so that the image of the wires on the plate might serve as marks of the cardinal points of the Sun's periphery, or of his

axis and equator, or for indicating any other desired positions. Besides being in the principal focus of the Webster, the brass disc was also in one of the conjugate foci of (*c*), another achromatic object glass (the Cox), the diameter of which is 1·4 inch, the principal focal length being 14·5 inches. It was placed 30·5 inches behind the disc, the dark slide (*d*) with photographic plate being in the other conjugate focus at a distance of 27·5 inches behind the Cox lens. The instrument was, in effect, two telescopes *tandem*, the hinder one looking at a total eclipse of the Sun in the focus of the foremost. The image of the Sun formed on the plate was of course direct. All stray light was carefully excluded.

Fig. 1.

With the exception of one exposure, No. 32, for which the Webster was stopped down to $\frac{7}{8}$ inch as an experiment, this lens was always employed with full aperture. The aperture of the Cox was continually being varied. Most of the earlier photographs were taken with full aperture, but as a rule subsequently it was stopped down either to $\frac{3}{8}$ inch or to $\frac{1}{4}$ inch. One object of these was to avoid a small fringe of outstanding colour arising from the fact that the focus employed was a conjugate and not the principal focus. The employment of either stop completely obviated this defect. Exposures of every conceivable duration were tried, some of the plates being exposed for so long that re-reversal took place. The times varied between the limits of half a second on the one side and, in the case of two exposures, as much as five minutes on the other. An exposure of above a minute yielded, as might have been expected, a negative of featureless blackness. On the whole the most promising plates were produced by exposures between ten seconds and a minute. When I say "promising," it is to be understood that I am referring solely to the hope of finding traces of corona, other portions of the plate being left to take their chance.

The position of the instrument in all the earlier attempts was such that the ends of the sides of the wooden tube of the instrument were parallel with the ends of the sides of the tube of the equatorial (also of square section) on which the instrument was mounted. Later on, when the sky continued clear for a sufficiently long interval, I made on two or three occasions three exposures in succession, of which the first was taken with the instrument in its normal position; the second, with it revolved entire on its line of collimation in one direction, and the third, in the opposite direction through an angle of 45° roughly. This

was to prevent the presence of any features of instrumental origin on the plate from being mistaken for features of corona. These positions of the instrument will be easily understood from the figures

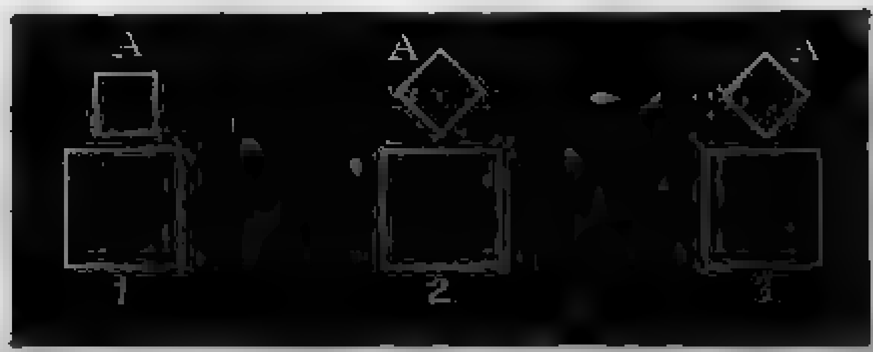


FIG. 2.

Here the lower squares represent the open end of the Newtonian equatorial, the upper ones that of the coronal instrument, A being the same side in each.

But though occasionally I fancied that distinct features could be detected on the negatives, I always had a sensation that others would never see them there, and that probably I saw them, or thought I saw them, because I wanted to see them. There is, however, one striking point about many of them, viz. that viewed from a distance of eight to ten feet they look exactly like a photograph of a total eclipse. This is especially true of some of the prints.

On the whole I think there can be little doubt that any likeness to true corona on the plates is produced, perhaps to a small extent by halation, but chiefly by sky glare. This last is no doubt the enemy that stands in the way between us and the corona. To cause a total eclipse in an instrument is comparatively easy, but to overcome the powerful reflections of the photosphere from every particle floating in miles and miles of atmosphere is quite another thing. The denser deposit in close proximity to the circumference of the image of the disc on some of the plates is, I think, to be ascribed to diffraction from the edge of the disc, of which there was some, though not much.

On the night of November 27 I gave an exposure of five minutes on the full Moon, with a view to discover how much apparent corona was due to sky glare. The Cox lens was for this purpose stopped down to $\frac{3}{8}$ inch to avoid any suspicion of colour fringe. Though from the prolonged exposure there is a slight close-fitting ring of halo round the image of the disc, there is a remarkable absence of anything of the kind at a greater distance, and a print of this plate viewed at a distance of eight or ten feet bears no resemblance whatever to a total eclipse, as I remarked was the case with some of the solar photographs.

A feature of most of the plates—it may be a feature of all negatives—having practically no previous experience, I cannot

tell—is that they show, or appear to show, more detail when viewed by reflected than when seen by transmitted light. Held up to the window, one often sees nothing but a faint image of the disc surrounded by a nebulous region of neither light nor shadow; but when backed by a sheet of white paper, it is in some cases difficult to believe that there is not *some* trace of genuine corona. The same was often seen just as the image was first showing itself in the developer. For all I know, however, this may be a characteristic of all developments. The plates used throughout were Sandell Triple-coated, the developer adopted being methol.

In the following list of plates the numbers in the column "Position" refer to fig. 2, in which 1 is the normal position, 2 that in which the top of the instrument was rotated about 45° to the west, and 3 that in which it was rotated about 45° in the opposite direction. The column headed "Aperture" refers to that of the Cox lens.

No.	Date. 1898		G.M.T.	Position.	Aperture.	Exposure.	Remarks.
1	July	27	3·40	1	F.	2 sec.	
2	"	30	0·30	1	F.	6 sec.	
3	"	31	3·10	1	F.	10 sec.	Negative seemed to give a faint trace of corona.
4	Aug.	7	4·25	1	F.	15 sec.	One of the best, if one may say so of any.
5	"	9	0·30	1	1/16	30 sec.	
6	"	10	23·10	1	1/8	½ sec.	Spoilt in development.
7	"	10	23·30	1	1/16	40 sec.	
8	"	20	3·25	1	¼	90 sec.	Instrument jarred in opening shutter.
9	"	23		1	¼	3 min.	Not entered till later. Hour forgotten.
10	Sept.	2	3·30	1	¼	4 min.	No good.
11	"	2	11·30	1	¼	5 min.	The Moon. Spoilt owing to non-provision for proper motion in Dec.
12	"	2	23·0	1	¼	5 min.	Useless.
13	Oct.	11	23·30	1	¼	5 min.	
14	"	12	Noon	1	¼	1 min.	Reversal taken place.
15	"	23	22·15	1	¼	5 sec.	Jarred at opening.
16	"	23	22·30	1	¼	5 sec.	
17	"	29	20·30	2	¼	5 sec.	
18	"	29	21·0	3	¼	5 sec.	
19	"	29	22·15	1	[illegible]	5 sec.	Clear intervals very short.
20	Nov.	3	23·5	1	¼	5 sec.	
21	"	3	23·20	2	¼	5 sec.	

No.	Date.		G.M.T.	Position.	Aperture.	Exposure.	Remarks.
	1898						
22	Nov.	3	23·40	3	¼	5 sec.	Sky getting a little white.
23	"	13	0·40	2	¼	10 sec.	Fogged owing to accident to shutter.
24	"	13	1·0	2	¼	10 sec.	
25	"	18	0·40	2	F.	15 sec.	Photosphere got exposed.
26	"	18	1·0	3	F.	15 sec.	Spoilt.
27	"	18	1·10	3	F.	15 sec.	Wind rising a little.
28	"	21	22·45	1	F.	15 sec.	Slight shake at opening.
29	"	21	23·8	2	F.	15 sec.	
30	"	22	Noon	3	F.	15 sec.	
31	"	27	10·25	1	⅛	5 min.	The full Moon. Excellent negative.
32	"	29	23·50	1	¼	1 sec.	The Webster was also stopped to ⅛ inch.
	1899.						
33	Jan.	4	23·45	1	¼	½ sec.	

Eclipse of the Moon, 1898 *December* 27. By Rev. Walter Sidgreaves, S.J.

The night of the 27th was on the whole remarkably favourable for the physical observations connected with the passage of the Earth's shadow across the Moon's disc. The sky showed a clearness of our atmosphere seldom excelled, but often observed on the break-up of storm clouds. Our attention, however, had been confined, from the beginning, to the accurate timing of the occultations and reappearances of small stars near and during totality. But incidentally the following notes of the appearance of the Moon were made. My own impressions, with unaided eye, were: 1. That the arc-margin of the shadow as it advanced on the Moon was solid and sharp. 2. That the shadow remained dark, without colour, until the silvery-white crescent vanished at totality. 3. That after totality the change of appearances might be likened to a colour-repetition of an earlier phase; in which the dark gibbous portion assumed the colour of a copper plate after cooling down from a bright red heat, and the remaining crescent glowed with a bright yellow, about the tint of the carbon film of an electric glow-lamp when not quite "full." 4. That the bright yellow cap, as was expected, disappeared at mid-totality, and reappeared on the side of approaching light with the approaching end of totality. 5. That the contrast brightness of the eclipsed limb at the early stages of partial eclipse was as marked as on the Earth-shine limb of a new Moon.

All answers to queries put to casual observers agreed in a reddish-brown colour of the Moon when fully eclipsed, terminating in a lighter cap. Father Cortie's impressions from a telescopic view are given in his own words as follows :—

"My attention was occupied, even after the beginning of the eclipse, in the selection of a suitable eye-piece for the observation of the occultations of stars. Hence no attempt was made to time the first appearance of the shadow, nor yet its passage across the more marked features of the lunar surface. The penumbra was well seen on the Moon's limb, in the form of a crape-like gauze, for some minutes before the appearance of the umbra, into which it seemed gradually to merge. As the shadow advanced to cover the Moon, the penumbra was just noticeable extending to a distance of about one-tenth of the lunar radius along its edge. This and the following observations, except where specially noted, were all made with the 15-inch Perry Memorial telescope, using a power of 47, which had now been selected as the most suitable to give the necessary separation of the ninth magnitude stars which were to be occulted. The edge of the shadow was very dark, seemingly for about a fifth of the lunar radius, when it gradually merged into a bright reddish-copper tint. A careful search was made along the boundary of the shadow in order to detect any possible irregularities in its contour. I changed the powers for this purpose, and used one as high as 350 diameters. No irregularity was to be seen, but the extreme edge of the shadow appeared like the nap or hairy surface of cloth. All the lunar craters and seas were perfectly visible and well defined, even through the darkest part of the shadow. The first two occultations were obtained before totality was completed, and these were the best. But in all three cases of immersion which were observed, the stars seemed to eat their way into the lunar disc for a marked distance before extinction. They appeared as little yellow dots on the coppery surface, and they disappeared instantly, without the slightest lagging. After totality was complete passing clouds began to be very troublesome, so that, besides causing me to miss the greater number of occultations, the three others secured, especially the emersions, are not so reliable. About midnight, while following a star near the N. point of the Moon, which would only have been some seven minutes behind the lunar disc, I was very much struck by the appearance of a greyish-white segment of the shadow below the copper-coloured portion. In its thickest part it would not have reached as far as the crater *Plato*. It then extended into the N.E. quadrant also. Further observations were prevented by clouds. But this whitish appearance was so remarkable that I called Mr. Ronchetti to come and view it in the telescope.

"During the progress of the eclipse I had occasion to view the Moon through the 3-inch Cooke finder, attached to the equatorial. The black edge of the advancing shadow was remarkably clear-cut and regular, and during totality the coppery image appeared

to be rather more greyish in tint than when viewed with the 15-inch. To the unaided eye the edge of the advancing shadow appeared quite solid and black. The general appearance of this eclipse was in marked contrast to that of 1884 October 4, which was so dark that, had I not been following the Moon with a telescope, I doubt whether I could have picked it up without the aid of circles."

The following notes were made by Mr. James Rowland, one of my students, who observed the eclipse with the 3½-inch equatorial refractor of the Students' Observatory.

"9.55 G.M.T. Umbra well on. Edge clearly seen to be shaded off into penumbra. Limb of Moon clearly visible in deepest shadow. Colour of shadow might be described as dark sepia.

"10.8. Dark limb of Moon deep copper coloured, but more tinged with red. Preceding edge of shadow appeared darker and of a colder tint than rest (probably contrast-effect).

"10.15. Shadow becoming redder. Crater Copernicus appeared bright through shadow. Shadow still shading off, and dark limb a deep red; but seas showed black."

"After totality much of the redness disappeared, and the colour might be described as a deep copper inclining to yellow rather than to red."

The observing arrangements for the occultations were: Father Cortie at the telescope, Mr. Ronchetti with the chronometer, and myself with the transit instrument. The latter arrangement was deemed necessary on account of the previous unfavourable weather; and fortunately the meridional sky remained clear throughout until near midnight. But the meridian passage of the eclipsed Moon was lost in the clouds.

The method of timing the occultations was the nautical method of "calling." It was at first intended to follow the eye and ear method as more exact; but considering the chances of confusion by occultations and reappearances following close upon one another, and by the interruptions of passing small clouds, it was decided to free the observer from the task of keeping his attention on the beats of the chronometer. My own experiences at Madagascar with time signals between the Transit of Venus observatory and H.M.S. *Fawn*, led me to the conviction that the "calling" system gave a time necessarily late by about 0·2 second; and I have not hesitated to apply this correction to the observed times of disappearance and reappearance.

The five stars observed have been identified as numbers 39, 45, 46, 32, and 39 of the Pulkova Catalogue of small stars eclipsed.

The following notes of the observer were made at the times of observation:

No. 39	Occultation.	Time	very good.
45	do.	do.	good.
46	do.	do.	fairly good.

32 Reappearance. Time late; seen close to limb, but actual reappearance missed.

39 Reappearance. Time fairly good.

			h	m	s
No.	39	G.M.T.	10	47	0·6
	45	do.	10	51	32·2
	46	do.	11	0	57·5
	32	do.	11	31	39·3
	39	do.	11	44	4·6

Stonyhurst College Observatory:
1899 *January* 10.

Occultations of Stars during the Lunar Eclipse of 1898 *December* 27, *observed at the Liverpool Observatory.* By W. E. Plummer, M.A.

The following observations of occultations during the eclipse of December 27, last year, were made in consequence of a communication received from the Pulkova Observatory. The conditions for observation were not very favourable. A heavy gale of wind blowing at the time interfered with the counting of the seconds of the clock, and the definition was much below the average. In consequence of this bad definition faint stars became confused with the limb when nearly in contact. As far as possible the stars have been identified with those given in the catalogue supplied by the Pulkova Observatory. It is curious that no star has been identified with those observed between $11^h\ 24^m$ and $11^h\ 50^m$, but it is believed that the entries at the time of observation and the reductions are correct. I have nothing to add concerning the position of the observatory to that given in the *Nautical Almanac.* The power employed was 78 on an 8-inch equatorial.

Immersion.

Name of Star.		G.M.T. of Disappearance. h m s	Remarks.
Anon.		10 43 59·5	Total phase not complete
B.D. 23° No.	1398	10 46 3·3	Very faint at limb
23	1402	10 50 5·2	
23	1403	10 59 37·4	
22	1385	11 23 59·6	Doubtful to some seconds.
Anon.		11 30 46·6	
		11 32 42·4	
		11 44 48·5	
		11 46 30·7	
		11 48 36·0	Possibly. B.D. 22° No. 1392
B.D. 22	1397	12 13 14·0	
23	1415	12 13 59·1	

Emersion.

Name of Star.		G.M.T. when first seen. h m s	Remarks.
Anon.		11 11 17·2	Possibly some confusion with B.D. 22° No. 1368.
B.D. 22° No. 1369		11 12 49·9	
23	1389	11 25 40·3	
Anon.		11 50 22·8	Should have been seen earlier.
B.D. 23° No. 1407		12 6 29·1	Very well seen.
23	1402	12 9 31·6	
22	1385	12 18 48·1	Left a satisfactory impression of accuracy.
23	1403	12 18 58·1	

Liverpool Observatory,
1899 January 10.

Observations of Eros (1898 *DQ*), *made at the Royal Observatory, Greenwich, with the* 30-*inch Reflector of the Thompson Equatorial.*

(*Communicated by the Astronomer Royal.*)

Two photographs of this planet were obtained with the 30-inch reflector on 1899 January 10. The electric hand-control was used to diminish the trail of the planet in Right Ascension. In the first photograph this was not effected very satisfactorily, and though the planet is shown plainly the trails of the stars are not uniform. In the second photograph two exposures of five minutes and four minutes respectively were given, and the images of both stars and planet are good. The second photograph only has been measured in the astrographic simplex micrometer. Four measures were made of each image of the planet by one observer, and two of each of the reference stars in reversed positions of the plate.

The positions of the reference stars were obtained from the catalogue of the *Astronomische Gesellschaft* Albany, and Leipzig II. Zones, the latter being kindly communicated in manuscript by Professor Bruns, the director of the Leipzig Observatory. Rectangular coordinates were computed from these and compared with the measures; linear corrections of the form $ax+by+c$ and $dx+ey+f$ were deduced and applied to the measured coordinates of the planet and reference stars.

The apparent position of the planet thus obtained is: –

Date.	G.M.T.	App. R.A.	App. Dec.	log. Δ.	Cor. for Par R.A.	Cor. for Par Dec.
	h m s	h m s	° ′ ″		s	″
1899 Jan. 10	6 11 27	23 14 30·31	5 38 58·8	0·1890	+0·14	+4·15

The resulting corrections to the ephemeris given by M. Fayet in *Astr. Nachr.*, No. 3538, are

R.A.	Dec.
s	″
+2·05	+17·7.

The following table gives the assumed places of the reference stars and the apparent corrections obtained from the measures of the photograph :—

Zone and No. in B.D.	Mag.	Assumed R.A. 1899·0.	Appar. Cor.	Assumed Dec. 1899·0.	Appar. Cor.	Approx. Distance of Star from Centre of Plate.
°		h m s	s	° ′ ″	″	′
5·5152	[illegible]	23 11 12·06	0·00	+6 2 17·7	0·0	58
5·5153	8·8	23 11 18·30	+ ·11	+6 0 6·5	+0·7	56
4·4989	[illegible]	23 11 59·38	− ·03	+4 53 30·1	+1·3	[illegible]
5·5154	9·2	23 12 5·71	− ·12	+5 18 4·3	−0·2	44
6·5139	9·0	23 12 8·53	+ ·09	+6 33 59·4	−0·1	68
5·5155	9·0	23 12 26·41	− ·07	+5 58 46·1	+0·7	40
4·4991	9·1	23 13 37·47	− [illegible]	+4 54 7·8	+0·6	47
[illegible]	8·0	23 13 43·27	− ·05	+4 51 22·9	+0·1	50
6·5141	7·2	23 14 12·59	+ ·08	+6 39 45·9	−0·5	63
5·5157	8·5	23 14 20·65	+ [illegible]	+5 20 1·0	−1·7	19
5·5158	9·1	23 14 35·27	− ·04	+5 18 1·0	−1·5	20
4·4995	8·9	23 14 58·66	− ·07	+5 5 41·1	−0·6	32
4·4996	9·0	23 15 1·42	+ ·02	+4 45 43·7	+1·2	[illegible]
6·5143	8·6	23 15 11·37	− ·09	+6 19 7·5	+0·8	42
6·5145	8·6	23 16 6·73	+ ·01	+6 25 52·4	−0·3	52
5·5160	9·0	23 16 42·44	·00	+6 8 32·1	−0·2	42
6·5146	9·6	23 16 43·88	− ·04	+6 41 5·1	−0·4	70
4·4998	8·7	23 16 54·74	+ ·08	+4 57 3·8	+1·6	52
5·5161	[illegible]	24 17 13·17	− ·02	+6 5 50·5	−0·8	46
4·4999	8·9	23 17 19·50	+ ·08	+4 56 48·9	−0·3	56
5·5162	9·0	23 17 51·71	+ ·03	+5 59 50·5	0·0	51
4·5002	9·6	23 17 58·39	+ ·05	+5 3 21·2	−0·7	59
Mean.		23 14 43		+5 39 42		

The approximate centre of the plate is at R.A. $23^{h}\ 14^{m}\ 45^{s}$. Dec. $+5°\ 38'$. It will be seen that the reference stars are at some distance from the centre of the plate, so that their positions may be to some extent affected by optical distortion. As, how-

ever, the planet is within 5′ of the mean position of the reference stars, and very near the centre of the field, the effect on its position would be very small.

Royal Observatory, Greenwich:
1899 January 21.

Note on the Photographs of the Satellite of Neptune taken with the 30-inch Reflector and 26-inch Refractor of the Thompson Equatorial.

(*Communicated by the Astronomer Royal.*)

Photographs of the satellite of *Neptune* have been taken as follows:—

Date.		Instrument.	Exposure.
1898 Dec.	23	30-inch reflector.	4^m and 2^m.
1899 Jan.	1	,, ,,	5^m and 4^m.
,,	5	26-inch refractor.	21^m.
,,	9	,, ,,	14^m.
,,	9	30-inch reflector.	5^m, 4^m and 3^m.
,,	10	,, ,,	5^m, 4^m and 3^m.
,,	11	,, ,,	5^m, $3\frac{1}{2}^m$ and 2^m.

These photographs give good images of the satellite well separated from *Neptune*. As yet only three of the photographs have been measured, pending the adaptation of a micrometer which was formerly used for the measurement of solar photographs.

The images of *Neptune* with the reflector vary from 10″ to 15″ in diameter. Those with the refractor are about 18″ in diameter.

[Since the date of this note an occulting screen has been adapted to the plate-holder of the 26-inch refractor, so that short exposures can be given for the planet during the long exposure for the satellite, and thus an image of *Neptune* of very small diameter has been obtained, the exposure on the satellite being 20^m, so that the position angle and distance can be measured with great accuracy.]

Royal Observatory, Greenwich:
1899 January 11.

Observations of Occultations of Stars and Planets by the Moon and of Phenomena of Jupiter's Satellites made at the Royal Observatory, Greenwich, in the Year 1898.

(*Communicated by the Astronomer Royal.*)

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h	m	s	Observer.
1898. Jan. 3	Disapp. 17 Tauri	28-inch Equat.	300	Dark	7	13	8·5	D.
3	„ „	Altazimuth	100	„	7	13	8·5	H.
3	„ „	Sheepshanks Equat.	100	„	7	13	8·5	D. E.
3	„ „	Astrographic Equat.	225	„	7	13	8·5	W. B.
3	„ „	Detached Tel. No. 3	100	„	7	13	8·9	W.
3	„ B.D. + 23° No. 510	Astrographic Equat.	225	„	7	25	23·4	W. B.
3	„ B.D. + 23° No. 517	28-inch Equat.	300	„	7	41	8·2	D.
3	„ „	Corbett Tel.	100	„	7	41	9·1	H.
3	„ „	Sheepshanks Equat.	100	„	7	41	9·7	D. E.
3	„ 23 Tauri	28-inch Equat.	300	„	8	1	26·7	D.
3	„ „	Merz Tel.	?	„	8	1	(27·9)	C.
3	„ „	Corbett Tel.	100	„	8	1	26·7	H.
3	„ „	Sheepshanks Equat.	100	„	8	1	26·8	D. E.
3	„ W.B. (2) III. 845	28-inch Equat.	300	„	8	4	58·8	D.
3	„ „	Corbett Tel.	100	„	8	4	59·4	H.
3	„ „	Sheepshanks Equat.	100	„	8	4	59·5	D. E.

Day	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation.	Observer.
1898.					h m s	
Jan. 3	Disapp. W.B. (2) III. 846	28-inch Equat.	300	Dark	8 5 32·0	D.
3	,, ,,	Corbett Tel.	100	,,	8 5 33·0	H.
3	,, ,,	Sheepshanks Equat.	100	,,	8 5 32·7	D. E.
3	,, B.D. + 23° No. 523	28-inch Equat.	300	,,	8 20 8·5	D.
3	,, ,,	Corbett Tel.	100	,,	8 20 8·1	H.
3	,, ,,	Sheepshanks Equat.	100	,,	8 20 8·6	D. E.
3	Reapp. 17 Tauri	28-inch Equat.	300	Bright	8 27 (33·5)	D.
3	,, ,,	Merz Tel.	?	,,	8 27 (35·6)	C.
3	,, ,,	Corbett Tel.	100	,,	8 27 32·0	H.
3	,, ,,	Sheepshanks Equat.	100	,,	8 27 (38·3)	D. E.
3	,, ,,	Altazimuth	100	,,	8 27 (39·0)	W.
3	Disapp. B.D. + 23° No. 528	Sheepshanks Equat.	100	Dark	8 31 9·5	D. E.
3	,, B.D. + 23° No. 531	28-inch Equat.	300	,,	8 37 22·7	D.
3	,, ,,	Sheepshanks Equat.	100	,,	8 37 23·0	D. E.
3	,, B.D. + 23° No. 534	28-inch Equat.	300	,,	8 39 27·3	D.
3	,, ,,	Sheepshanks Equat.	100	,,	8 39 28·6	D. E.
3	,, 24 Tauri	28-inch Equat.	300	,,	8 39 59·3	D.
3	,, ,,	Corbett Tel.	100	,,	8 40 0·2	H.
3	,, ,,	Sheepshanks Equat.	100	,,	8 39 59·1	D. E.
3	,, ,,	Merz Tel.	?	,,	8 40 0·5	E. S.

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation.	Observer.
1898.					h m s	
Jan. 3	Disapp. ν Tauri	28-inch Equat.	300	Dark	8 45 10·3	D.
3	" "	Merz Tel.	?	"	8 45 11·2	C.
3 (a)	" "	Corbett Tel.	106	"	8 45 10·7	H.
3	" "	Sheepshanks Equat.	100	"	8 45 11·1	D. E.
3	" "	Altazimuth	100	"	8 45 10·9	W.
3	" "	Finder of Thompson Equat.	?	"	8 45 10·2	E. S.
3	" Pi. III. 151	28-inch Equat.	300	"	8 57 21·4	D.
3	" "	Corbett Tel.	100	"	8 57 21·5	H.
3	" "	Sheepshanks Equat.	100	"	8 57 21·9	D. E.
3	Reapp. 23 Tauri	28-inch Equat.	300	Bright	9 11 4·2	D.
3	" "	Corbett Tel.	100	"	9 11 4·1	H.
3	" "	Altazimuth	100	"	9 11 3·8	W.
3	Disapp. B.D. + 23° No 549	Sheepshanks Equat.	100	Dark	9 25 29·6	D. E.
5	" Bradley 523	28-inch Equat.	300	"	9 38 14·6	D.
3	" "	Corbett Tel.	100	"	9 38 14·8	H.
3	" "	Sheepshanks Equat.	100	"	9 38 14·4	D. E.
3	" 28 Tauri	Corbett Tel.	100	"	9 53 52·2	D.
3	" "	Merz Tel.	?	"	9 53 51·9	C.
3	" "	28-inch Equat.	300	"	9 53 52·4	H.
3	" "	Sheepshanks Equat.	100	"	9 53 52·5	D. E.

Day.	Phenomenon.	Telescope.	Power.	Moon's limb.	Mean Solar Time of Observation. h m s	Observer.
898 Jan. 3	Disapp. 28 Tauri	Altazimuth	100	Dark	9 53 52·8	W.
3	" 27 Tauri	Corbett Tel	100	"	9 59 46·7	D.
3	" "	Merz Tel.	?	"	9 59 (47·9)	C.
3	" "	28-inch Equat.	300	"	9 59 46·9	H.
3	" "	Sheepshanks Equat.	100	"	9 59 47·1	D. E.
3	" "	Altazimuth	100	"	9 59 47·1	W.
3	" B. D. + 23° N. 562	Sheepshanks Equat.	100	"	10 3 19·0	D. E.
3	Reapp. η Tauri	28-inch Equat.	300	Bright	10 8 6·9	H.
3	Disapp. W. B. (2) III. 903.	Sheepshanks Equat.	100	Dark	10 11 37·7	D. E.
3	Reapp. 27 Tauri	Merz Tel.	?	Bright	10 58 52·2	E. S.
Mar. 13 (*b*)	Disapp. Antares	Sheepshanks Equat.	100	"	14 39 3·8	B.
13	Reapp. Antares	" "	100	Dark	15 49 2·1	"
Apr. 23 (*c*)	Disapp. 62 Tauri	" "	100	"	9 45 37·2	"
29	" ξ Leonis	Astrographic Equat.	250	"	12 59 23·3	W. B.
May 2	" Pi. XI. 167	Sheepshanks Equat.	100	"	11 23 58·1	A. C.
22 (*c*)	" Venus 1st Limb	" "	100	"	6 53 54·0	B.
22	" Venus 2nd Limb	28-inch Equat.	450	"	6 54 38·4	L.
22	" " "	Astrographic Equat.	225	"	6 54 36·9	H.
22	" " "	Sheepshanks Equat.	100	"	6 54 37·5	B.

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation.	Observer.
1898.					h m s	
May 22	Disapp. Venus 2nd Limb	Corbett Tel.	70	Dark	6 54 36·9	W. B.
22	Reapp. Venus 1st Limb	Astrographic Equat.	225	Bright	7 31 16·2	H.
22	„ Venus 2nd Limb	„ „	225	„	7 31 51·3	H.
22	„ „ „	Sheepshanks Equat.	100	„	7 31 49·8	B.
June 5	„ λ Sagittarii	Altazimuth	100	Dark	11 22 5·3	S.
Sept. 9	Disapp. Mars 1st Limb	Sheepshanks Equat.	55	Bright	1 30 31·1	A. C.
9 (*c*)	„ Mars 2nd Limb	„ „	55	„	1 30 40·1	A. C.
28	„ 16 Piscium	„ „	55	Dark	13 38 33·5	W. B.
28	„ „ „	Astrographic Equat.	225	„	13 38 32·8	H. F.
Nov. 22	„ 19 Piscium	„ „	225	„	7 8 50·6	H. F.
22	„ „ „	Sheepshanks Equat.	100	„	7 8 50·7	P. M.
29 (*d*)	Reapp. W. B. (2) V. 1577	„ „	100		11 48 59·0	B.
Dec. 23	Disapp. 47 Arietis	Corbett Tel.	100	„	9 3 20·8	H. F.
23	Reapp. „ „	Astrographic Equat.	225	Bright	10 11 18·2	S.

Notes.

(*a*) Seemed to take 0·2 sec. to disappear. The time noted is that of final disappearance.
(*b*) Seemed to encroach on limb before disappearance.
(*c*) Not considered a good observation.
(*d*) Not considered a good observation. Reappeared very near the bright limb. Cloudy.

Phenomena of Jupiter's Satellites.

Day.	Satellite.	Phenomenon.	Telescope.	Power	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
1898.					h m s	h m s	
Feb. 7	II. (a)	Occ. R. First seen	Altazimuth	100	11 42 45·18	11 40	A. C.
7	II.	Bisection	"	"	11 44 59·81		"
7	II.	Last contact	"	"	11 49 31·07		"
Mar. 2	I. (b)	Ecl. D. Last seen	Sheepshanks Equat.	120	10 44 56·06	10 45 50	B.
2	II. (c)	Tr. Ing. First contact	"	"	10 41 36·61	10 51	"
2	II.	Last contact	"	"	10 48 5·54		"
2	II. (d)	Tr. Egr. First contact	"	"	13 13 11·75	13 19	"
2	II.	Bisection	"	"	13 17 11·10		"
2	II.	Last contact	"	"	13 20 37·53		"
Apr. 16	I.	Tr. Ing. First contact	"	100	13 18 51·39	13 21	A. C.
16	I.	Bisection	"	"	13 20 46·08		"
16	I.	Last contact	"	"	13 22 50·73		"
19	II.	Occ. D. First contact	"	120	8 3 1·65	8 7	B.
19	II.	Bisection	"	"	8 5 21·27		"
19	II.	Last seen	"	"	8 8 20·78		"
May 2	I.	Tr. Ing. First contact	"	"	11 17 57·09	11 20	A. C.
2	I.	Bisection	"	"	11 19 55·76		"
2	I.	Last contact	"	"	11 22 34·33		"
3	I.	Occ. D. First contact	"	"	8 27 8·15	8 29	H.
3	I.	Bisection	"	"	8 28 52·86		"
3	I.	Last seen	"	"	8 30 48·57		"
14	II. (e)	Ecl. R. First seen	"	"	8 55 54·28	8 56 6	A. C.

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1898. May 14	II.	Full brightness	Sheepshanks Equat.	120	8 57 47·96		A.C.
18	I.	Tr. Ing. First contact	"	"	9 23 27·79	9 24	"
18	I.	Bisection	"	"	9 26 5·35		"
18	I.	Last contact	"	"	9 28 11.02		"
18	I.	Tr. Egr. First contact	"	"	11 36 46·99	11 40	"
18	I.	Bisection	"	"	11 38 39·68		"
18	I.	Last contact	"	"	11 41 4·30		"
June 10	I.	Tr. Ing. First contact	"	"	9 27 50·26	9 27	W.
10	I.	Bisection	"	"	9 29 29·99		"
10	I.	Last contact	"	"	9 31 59·58		"
10	III.	Tr. Ing. First contact	"	"	10 23 1·20	10 23	"
10	III.	Bisection	"	"	10 25 10·84		"
10	III.	Last contact	"	"	10 27 0·54		"
21	III. (f)	Ecl. D. Began to fade	Astrog. Equat.	225	9 39 23·21	9 41 11	C. D.
21	III.	Bisection	"	"	9 41 12·91		"
21	III.	Last seen	"	"	9 46 21·06		"

Notes.

(a) Jupiter unsteady. (b) Cloudy. (c) Cloudy, definition very bad. (d) Probably late.
(e) Twilight and slight haze. (f) Definition poor.

The initials D., C., L., H., A. C., B., C. D., D. E., W. B., H. F., S., W., P. M., and E. S., are those of Mr. Dyson, Mr. Cowell, Mr. Lewis, Mr. Hollis, Mr. Crommelin, Mr. Bryant, Mr. Davidson, Mr. Edney, Mr. Bowyer, Mr. Furner, Mr. Showell, Mr. Witchell, Mr. Melotte, and Mr. Skells respectively.

Royal Observatory, Greenwich: 1899 January 12.

On the Value of Possible Observations from Free Balloons.

By the Rev. J. M. Bacon.

During the past summer and autumn I have made a series of balloon ascents, seven in all, under varying conditions and at different hours of the day and night, a principal object being to gather fresh information as to states of atmosphere prevailing at different heights in our own skies, with the view of determining the likelihood of securing certain observations possessed of a new value :—

The observational work I more particularly had in view was :—

(1) To determine how much more of the solar spectrum could be photographed at a great height, more particularly its extension into the ultra-violet.

(2) To photograph the solar corona by such methods as have been adopted by Sir W. Huggins under circumstances of diminished air-glare.

(3) To undertake such visual observations as could be usefully made with low power under exceptional conditions of atmosphere.

Inasmuch as all, or nearly all, of such observations have already been undertaken from observatories standing on high elevations, it was essential to determine in what particulars the atmospheric conditions prevailing in mid-air above plain country differ from those recorded at like altitudes on mountain heights.

The difference appears of a most important nature. Abundant testimony shows that, during night hours at least, currents are constantly ascending or descending mountain slopes, and it can scarcely be doubted that the air in these regions is also seriously affected by radiation from heated rock surfaces. Moreover, I am led to suppose that, whether by reason of its attraction or other cause, a denser film of air is always and everywhere clinging to the actual surface of Earth.

The character of the late summer was doubtless somewhat exceptionally uniform, but it is noteworthy that in all daylight ascents a very obvious haze was always surmounted at heights varying from 4,000 feet to 6,000 feet, and this possessed a well-defined limit, above which the sky always became bluer in a marked degree. The colour would sometimes assume the deepest blue, though no darkening of the sky was observed.

During an ascent made on a serene and cloudless moonlight night it was found that an unsteadiness of atmosphere noticeable on the ground had entirely disappeared before 6,000 feet was reached. At this height the scintillation of the stars had become less, and the Moon shone with almost intolerable brilliance in the clearest sky. As soon, however, as the descent had been

effected it was noticed that the Moon was surrounded by a vivid circle of iridescence, which remained unchanged during the remainder of the night.

The presence of haze was not made visible by moonlight, but by means of an extremely sensitive air thermometer I detected distinct and definite layers of air, many degrees warmer than on Earth, at different heights; and I conjectured from the fickle and otherwise unaccountable behaviour of ground echoes that these existed in detached pools rather than in extended strata.

The period of observation did not exceed two hours, but at frequent intervals the blast of a horn was blown, and its echo from Earth attentively listened for in the absolute silence prevailing, care being also taken to repeat the experiment many times to make sure of securing some good reflection of sound. These echoes would occasionally be obstinately silent at 1,000 feet, and again, during certain intervals, become easily heard at more than twice that height; and it should be mentioned that this peculiarity had never been observed during day ascents.

The travel overhead of air of the nature that this experiment indicated would sufficiently account for its unsteadiness as observed below. Moreover, a number of uniform photographic exposures made at different intervals showed that the actinic action of light, as a whole, increased with height, but varied according to localities. In a like manner, also, dust in suspension decreased generally with altitude, but also varied with locality.

I would point out that the amount of glare-causing matter (as noticed from above) existing in lower strata does not appear to depend on hygrometric conditions; and again, that when much glare is present in lower levels, the air may still be in such a condition—presumably very homogeneous and steady—as to be extraordinarily transparent to waves of sound.

In proof of this I proceed to show three series of photographs. In two of these it will be noticed that up to a height of nearly 3,000 feet the characteristic glare reflected from matter in suspension beneath is equally absent, and to a very unusual extent, yet hygrometric conditions were quite opposite in degree. In the third case, where no bright pictures could be taken, in spite of brilliant Sun, echoes off the ground were caught at a greater height than on any other occasion during the summer.

It would appear probable that those conditions, considered above, which must be inimical to good definition would be more or less apparent at all stations on the Earth's surface, whereas they, as well as a very large proportion of prevalent cloud, could be surmounted at a moderate height by an aërostatic observatory.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIX. JANUARY 13, 1899—(*continued*). No. 4

Remarks on the Paper by Professor H. H. Turner; together with another suggested explanation of Stationary Radiant-points of Meteors. By Professor A. S. Herschel, M.A., D.C.L., F.R.S.

The mode of accounting for stationary radiant-points proposed in Professor Turner's paper certainly reveals to us in a most clearly expounded way, and in a very elegant and ingenious shape, a real *raison d'être* for their existence. We should not, of course expect coherence among the elements of a meteor-swarm so as to obliterate the Earth's deflecting action on the individual meteors and to allow a cluster, after the Earth's central passage through it, to resume its course with its radiant-point unaltered, but with a new position of its node impressed upon its orbit. But what would in that case be true for meteorites' individual deflections, that those which pass equally far from the Earth in front of and behind it receive from the Earth's attraction equal but opposite deflections which, in a cohering swarm, might be supposed to cancel each other, may be said of an individual meteorite, which will in a very long time pass as often behind as in front of the Earth, and will thus on an average undergo no material deflection. But through all these self-corrections the displacement of the node, of which Professor Turner has so well described and pointed out the existence and nature in his paper, is constantly renewed at each return, and thus goes on accumulating. A *vera causa* for the existences of such meteor-streams with fixed divergences and long durations, has thus been clearly traced; and though its

action on swift-moving meteor-streams must naturally be slow, it may yet have sufficed, in long ages, to displace the nodes of some of the meteors of even those swift streams considerably.

We are assured, on the authorities of good observers, that the meteors from stationary radiant-points change their speeds progressively during the several months in which occasional flights of them sometimes continue to be visible, in perfect accordance, like the meteors of other streams, with the near or remote distances of their radiant-points from the constantly moving apex of the Earth's way, and that they accordingly present, in this way, even from a single radiant-centre, the same varieties of meteor-speeds as other meteors.

But the case differs in a stationary system of showers produced in the manner of Professor Turner's explanation; since from the permanency of both relative velocity and radiant-point of the meteor bodies' orbits during the Earth's shifting action on their nodes, a cluster of slow-moving meteors like, for example, the *Aquilids* in August, would remain a slow-moving one where their retrograded node is shifted round the Earth's orbit to April; albeit there, on the evidence of observers, the shower of April *Aquilids* is an extremely swift one: and there are many other such examples.

As much encouragement would be afforded to good meteor observations by any complete and satisfactory theory of stationary radiant systems, and as the difficulty of the quest for its solution makes lights thrown on this problem from as many different directions as can be obtained desirable, I will venture to describe a view to which I have been just lately led by thinking over Mr. Proctor's suggestive ideas ("Five Orders of Meteor Streams or Comets," *Monthly Notices*, vol. xlvi. p. 405, 1885, December) of the ejection of hyperbolic comets, and of enormously swift-moving shooting-stars from "giant suns like *Sirius*," as also some original illustrations published from time to time by Mr. W. H. S. Monck, of the mechanical conditions presented by this meteor problem.

Were cosmical streams of matter to be projected from large stars with such immense velocities that the Earth's orbital velocity and the Sun's attraction would both be insignificant quantities beside them, and were they to dash past the Sun and to produce on the Earth, as Mr. Proctor thought possible, the phenomenon of meteor-streams with radiant-points sensibly fixed and independent of the Earth's motion and position in its orbit, there can be no doubt that the enormous speeds of such meteors would have been long ago detected; and no such prodigious velocities of shooting-stars have, in fact, been ever yet recorded. But ages have passed by since the solar system assumed its present form, and many such visits may have been made to it in that time by streams of cosmical matter moving with such extremely hyperbolic velocities that the bodies' meteor speeds relative to the Earth in any part of its orbit might all be

regarded as nearly parallel in direction. The bygone epochs of such visits may have been when the Earth was still accompanied by a denser ring of bodies (perhaps like the annulus of matter round the planet *Saturn*) than any now to be found at the outer confines of the zodiacal light; and through such a ring of bodies, moving round nearly the same track, with nearly the same velocity as the Earth has in its present orbit, the cosmical stream might dash, expelling many members from the ring, as a tree is robbed of many of its leaves by a strong gust of wind sweeping through it; and it is here suggested now that it is the *débris* of such gusts, *not the gusts themselves* (as was originally suggested by Mr. Proctor in his above-mentioned paper), which we long afterwards, probably, behold showering down upon the earth as mixed comets and meteor systems with stationary radiant-points, the only visible chronicles, as we may say, remaining to us now of those long bygone celestial disasters.

The bodies struck out of their annular orbits had, before their dismemberments, velocities of their own nearly the same as the earth's orbital velocity; but, on receiving blows relatively directed from a nearly fixed relative radiant-point, they would compound the stationarily directed velocities of these relative blows or impulses with their own earth-orbital velocities, and would set off on new orbits round the Sun of very various sizes and shapes and degrees of inclination to the ecliptic. Were the gusts of cosmical dust possessed of ten or twenty times the speed which non-periodic comets have near the Earth's orbit, so as to dash past the solar system at rates of about 250 to 500 miles per second, and were a member of the Earth-ring to be overtaken directly *a tergo* by one of the cosmic dust-fragments, then, to convert it from a planet into a parabolic-pathed meteor-body, the ring-member's mass or inertia would require to be thirty- to sixty-fold the mass or inertia of the cosmic fragment, to allow the fragment's blow to add the needed 7 or 8 miles per second,* only, to the ring-body's original orbit velocity of about 18 miles per second. If below this proportion, the expelled body would receive a greater impressed velocity than this, and would never return in a closed orbit to its place of expulsion from the ring; but, if above it, the imparted velocity would be less, and the ejected body would describe a closed elliptic orbit round the Sun, and in the course of many returns to the Earth's orbit would probably be reabsorbed, in time, by the ring of bodies there; so that only ejected masses receiving nearly cometary velocities would, after the protracted length of time since that early solar system stage, be found returning now to the Earth's neighbourhood, either as shooting stars or, it might also even be, sometimes as comets.

It may be very fairly urged against these suppositions that

* Omitting, for the illustration, from the added speed, any further speed conferments required to overcome surrounding mass attractions.

almost any solid mass, however large, would be pierced through instantaneously by nearly any such impinging cosmic fragment, however small, and would suffer no deflection from its course; but the perforated matter would be carried forward, if not the mass itself, in the relative path-direction of the fragment, just as the luminous streaks of shooting stars pursue them on a straight course, and with all varieties of impressed velocities, through the Earth's atmosphere.

At each return of an ejected particle back to the Earth's and ring's route, if the Earth be struck and a shooting star produced, this meteor's relative or apparent radiant-point and actual meteor speed (or speed as apparent on the Earth), since the *Earth's* velocity is the same at the meeting-point as that which the *meteor* had there before it was ejected, must evidently be just the radiant-point and speed which were impressed on it by the blow with which the cosmic fragment struck it. That is to say, the observed radiant-point of all such meteors as compose the smoke and ashes of the ring, ejected from it by one single gust or volley from celestial spaces, will at any point of the Earth's course where it encounters such a meteor be the volley's relative radiant direction there, which has been assumed to be a nearly fixed, invariable one, from the volley's supposed enormously high speed of motion.

As regards the relative speed of the meteor as seen by observers on the Earth, since this, as was just now remarked, is precisely that with which the tempest of celestial missiles originally propelled the meteor, as a dust-flake in its wake, from some revolving masses of the ring, if we suppose this speed relative to the earth-ring (whether directed from the "quit" or from the "goal" of the Earth's way, or from anywhere between them), to have been just suitable (because that is a condition supposed to subsist among the generality of now occurring meteors), to launch the flakelet into space on some very long elliptic, nearly parabolic orbit, it is evident that on reappearing, after describing an orbit-circuit of such lengthy compass, as a meteor directed from just the radiant-point which the celestial volley's dust-scud first gave it, whether the radiant-point be near or far from the apex of the Earth's way, the accompanying apparent meteor-speed must necessarily be the theoretical parabolic-pathed meteor-speed for a radiant-point of the observed apex-elongation, and swift or slow accordingly, because it is the selfsame speed which, impressed originally on the meteoric flakelet, launched it on the parabolic path, or belonged in exactly this assigned relative way to an orbit of parabolic, or of very nearly parabolic form and compass. Thus both of the requirements of observation for a suitable solution of the apparently impenetrable fixed radiation problem are at least satisfied completely by this simply intelligible explanation (and perhaps not too far-fetched astronomical assumptions), that, in the first place, many ordinary meteor showers diverge with very prolonged

activities from nearly fixed radiant points; and secondly, that, with the changing distance of the radiant-point from the apex of the Earth's way, the meteors of such a long-enduring shower also vary in velocity in exactly the same way as is found to be usual among other shooting stars and large meteors at different elongations of their radiant-points from that apex. But among the meteors proceeding from one single flight of cosmic matter, both short and long period orbits (though the first only very rarely) may be expected to present themselves; and the same conclusion therefore may be drawn from this hypothesis as the result shown above to be deducible from Professor Turner's theory, that among their intermittent outbursts both solitary meteors and meteor clusters might occasionally be found proceeding from a stationary shower's radiant-point with abnormally slow velocities.

All the knowledge that has yet been obtained by observation respecting the real velocities of meteors, appears, however, to be both too limited in extent, and too far from sufficiently reliable to furnish any very decisive and important test of these velocity assumptions, or of the correctness or incorrectness of a theory of meteor-streams' perturbations. The usually accepted view of the prevailing forms and mode of distribution of ordinary meteor-streams is, indeed, that their orbits are in general parabolic, crossing the Earth's orbit pretty equally at all points, and indifferently from all directions, with a nearly constant parabolic velocity of about 26 miles per second. Through this even distribution the northern side of the Earth should, by the latter's motion in the ecliptic, meet a maximum of meteor frequency in September and October, and its southern side a maximum in March and April, which has, however, recently been quite disproved by Mr. G. C. Bompas, in a paper on the "Semi-annual Variation of Meteors,"* where it was shown that a maximum meteor frequency in September and October, and a minimum frequency in March and April, appear by Dr. Neumayer's observations at Melbourne to occur just similarly, though somewhat less pronounced, in the southern hemisphere as they are found to do in northern latitudes. The rise and fall of frequency, in fact, seems rather to depend on a certain local concentration of meteor-radiant-points among the constellations rising after sunset in the east in autumn, which Mr. Denning found very decided indications of in 1886,† in a general catalogue which he then prepared, arranged in right ascensions, of more than three thousand radiant-point determinations. In the sector of R.A. from 0° to 60°, the crowding of shower-centres, increasing rapidly from both sides to that small quarter of the sky, is $2\frac{1}{2}$ times as dense as in the opposite similar sector of R.A. (180° to 240°), where a minimum shower-density is reached from both sides very gradually. The exceptional fulness in meteor showers of the former region

* *Monthly Notices*, vol. liv. p. 531–538, 1894 June.

† W. F. Denning "Distribution of Meteor-streams," *Monthly Notices*, vol. xlvii. p. 35–39, 1886 November.

seems to be certainly not ascribable to abundant watching of the sky in August for the *Perseids*, because up till midnight then, a considerable part of the productive area is not yet visible above the east horizon. As the whole tract is also, in the autumn months, about 90° from the apex of the Earth's way; and as the latter apex, from its northing at dusk to its rising in N.E. at 8^h–11^h, is never through the autumn evenings more than 15°–30° below the northern horizon, it seems unaccountable why a region so far from the apex as this particularly emissive sector is, should be more thickly strewn with radiant-points than neighbouring tracts of the sky in *Orion*, *Cancer*, *Gemini*, *Lynx* and the circumpolar constellations, all very well visible and so much nearer to the apex. But there is, besides, another law of distribution which no doubt helps to give this region a peculiar prominence in the wide autumn prospect round the meteor-apex, which was very strikingly illustrated and discussed not long ago by Mr. Denning,* that far the greater proportion of the radiant-points which produce fireballs and bright meteors, is collected pretty closely along the neighbourhood of the ecliptic; and the latter, we may now further add, lies nearly level along the eastern horizon in the autumn evenings.

Besides these signs of orbit-grouping, suggesting external actions on meteor-streams' positions of some very powerful predominating natures, the very varying results of meteor-speed determinations also throw considerable doubt on the supposed constancy among the speeds and parabolic forms of meteor-orbits. As regards meteorites, a thorough research of their known path-lines led Professor Newton to a conclusion † that the "large meteorites, or stones in the solar system, agree much more closely with the group of comets of short period than with the comets whose orbits are nearly parabolic"; and they are "nearly all direct moving, unless those moving retrograde are prevented by their great speeds, perhaps, from reaching the ground in a solid form." Of 116 observed meteoritic falls, he found that "109 must have been following, while only seven met the earth."

The shower of stones at Pultusk (near Warsaw, 1868 January 30), however, according to Dr. Galle, overtook the Earth almost directly with a sensible speed of 17 miles per second, exceeding that for a parabolic orbit by 7 or 8 miles per second.‡ And a detonating fireball of great size on 1873 June 17, also, like the foregoing meteor, well observed at the Breslau Observatory, was independently found by Dr. Galle and Professor v. Niessl to have been similarly overtaking the Earth, a little obliquely, in the plane of the ecliptic, with an apparently

* W. F. Denning, "Zodiacal Radiants of Fireballs," *Monthly Notices*, vol. lvii. p. 561, 1897 May.

† Professor H. A. Newton "On the Relations of the Orbits of Meteorites to the Earth's Orbit." *Amer. Jour. Sci.*, 1888 July—shortly referred to, as above, by Dr. Downing, *Monthly Notices*, vol. liv. p. 544.

‡ *British Association Reports*, 1868, p. 389.

hyperbolic orbit-speed which seems to have been about between 28 and 38 miles per second.*

Even for closely allied and perhaps identical radiant-points, good observations occasionally give very varying velocities. Thus on 1874 April 9, and 1876 April 10, two large detonating fireballs passed over Bohemia and Hungary, whose real paths were carefully deduced from many good accounts of each, by Professor v. Niessl, together with their radiant-points, at 19°, +57°, and 17°, +57°, and their real meteor-speeds, which were found to be respectively 14 and 25·5 miles per second. The former velocity agrees closely with, but the latter is nearly as large again as the theoretical speed, 14·5 miles per second, of a meteor from this radiant-point in a parabolic orbit.† On 1877 May 30, Mr. Denning, at Bristol, and Mr. Corder, near Chelmsford, simultaneously observed a *Jupiter*-like bolide, which ended with a streak and flash, rather low in the E.N.E. at both the stations. Both of the accounts were noted as "accurate," and the meteor's real path of 90 miles in "two seconds" (as described at Bristol), at a considerable elevation (87 to 75 miles) over the German ocean, was found from the observations, by Mr. J. E. Clarke, to have had a radiant-point at 20°, +58°, or (as I have now projected it again from the observed paths) at 22°½, +57°½, and the immensely high velocity for this radiant-point—nearly the same in place with that of the two last-mentioned aërolitic meteors—of 45, instead of 25 miles per second!‡

Another similar example was presented by the bright, long-pathed fireball of January 21, last year (1898), of which from thirty-three discriptions of its course, Mr. Denning found the apparent radiant-point and velocity, 130°, +30°, and 34 miles per second; *vide* his map of real meteor paths in 1897–98, in *The Observatory* of 1898, October. On 1877 January 19, a similarly bright and long-pathed fireball passed westwards from over Milford Haven to over the Atlantic Ocean south of Ireland, from three or four of the best descriptions of which I was able to deduce a real speed of 35 miles per second, and apparent radiant-point 135°, +27° (±6°), while by a new comparison of the accounts, Professor von Niessl assigned for the radiant-point a position at 135°·5, +22°.§

A splendid fireball passed with such a loud detonation over the city of Prague on the evening of 1879 January 12, that houses were shaken, and even, it was said, window-panes were broken there. Numerous accounts of this fireball, collected by Professor von Niessl, showed its real course to have been from

* *British Association Reports*, 1874, p. 270–276.

† *British Association Reports*, 1877, p. 144–47.

‡ *Ibid.* p. 143.

§ *Monthly Notices*, vol. xxviii. p. 228, and vol. xxix. p. 281, 1878 and 1879, February; and also for this and the next meteor's real path descriptions, *Reports of the British Association*, 1877, p. 118 and 153, and 1879, p. 83–84, and *Sitzungsberichte* of the Vienna Academy, 1879 May 8 (*vide infra*.)

across the north-eastern frontier of Bohemia, near Breslau, to a low height of nine miles, about twenty-five miles west of Prague, the apparent radiant-point and real speed of flight (uncorrected, like the other similar results here noticed, for the Earth's attraction) having been 133°, +19°, and 17 miles per second.

The parabolic meteor-speeds for these three meteors' radiant-points should have been 20, 23, and 26, instead of 34, 35, and 17 miles per second. But the slowest of them was the most distinctly aërolitic; and all their paths may be compared together briefly, with two cometary radiants, and with neighbouring recorded meteor radiants of apparently two continuous shower-centres, in a table, thus :—

Cometary Radiants and Meteor-Shower Observers.		Dates of Shower-Nodes and of Cometary "Appulse" (ʊ). Shower I.	Shower II.	Cometary and Meteor Radiant-Points. Shower I.	Shower II.	Meteor-Speeds for Parabolic Orbits. m.p.s.	Apparent. Observed. m.p.s.
				° °	° °		
S. Masters	...	...	1867 Dec. 12	...	136+30	[illegible]	...
J. Schmidt	...	...	December	...	130+30	(33)	...
☄ 1680 ʊ	...	Dec. 26	...	132+21·5	...	31·5	...
Fire-balls	Detonating	1879 Jan. 12	...	133+19	—	26	17
	Silent ...	—	1877 Jan. 19	...	135+27	23	[illegible]
	Silent ...	...	1898 Jan. 21	...	130+30	20	34
☄ 1833 ʊ	...	...	Jan. 27	...	135+25	20·4	...
E. F. Sawyer	...	1880 Feb. 6-8	...	130+22	...	16·5	...
G. V. Schiaparelli and G. Zezioli		...	Feb 13	...	133+26	15	...

(Distinct showers from within 2° or 3° of position I., were also observed originally or deduced from foreign catalogues of meteor-paths by Mr. Denning, for February-March 12, and at frequent intervals between October 11, when Colonel Tupman recorded a shower in 1869, at 128°, +20°, and January 15. Some extension of shower II.'s duration was similarly traced by Mr. Denning in November and December, and by Mr. Corder in February-March; a shower was also noted in September by Mr. Greg, at 130°, +32°.) The two showers are included by Mr. Denning in his "Catalogue of 177 Apparently Stationary Radiant-points," *Astron. Nachrichten*, No. 3531, as Nos. 68, and 69, at 130°, +20°, October-January, and 132°, +31°, September-February; and the longitude and latitude positions are about 127°, +1°, and 125°, +13°. The Earth's apex, on January 15, was about 80° onwards in longitude from both the radiants, at about long. 205°.

Unless it is conceivable that meteor orbits may by some disturbing action be shifted, as this table seems to indicate, sometimes forwards and sometimes backwards in their nodes, without change of their radiant-points or of their relative speeds of motion past the earth, it must be evident from these, and from many other such examples, that real lengths and durations of meteor-flights,

and consequently their real speeds, are not in general very certainly determined. But rather anomalous real speeds have yet sometimes been unmistakably observed, and if the interest which attaches to them were more generally felt, there is really nothing easier than to include in every note of a meteor's flight a pretty exact estimate of the time which the meteor occupies in its passage: this may readily be done by repeating mentally (at one's usual rate of clear articulation) as much of the monosyllabic English alphabet as represents the flight's duration, either during the short flight or directly after it, and at the rate of about six letters to a second, or four seconds for one whole alphabet, pretty minutely exact time-estimates of meteors' durations may thus be very easily recorded.

A small bright fireball, well seen by Colonel Tupman at Greenwich, and by Mr. Corder, near Chelmsford, shot on the night of 1877 November 27, at a low height of 56 to 13 miles over the English Channel, as was shown by Colonel Tupman, from the mouth of the Thames to a little short of the French coast near St. Omer. To describe this real path of 78 miles the meteor occupied, as Colonel Tupman noted attentively while it moved along, between 15 and 20 seconds, with a real speed, accordingly, little if at all exceeding, Colonel Tupman felt assured, about 5–6 miles per second. But he has calculated orbit-paths of this fireball around the Sun on both limiting assumptions, that its meteor-speed may have been either $5\frac{3}{4}$ or $10\frac{1}{3}$ miles per second.* Now a satellite of the Earth would travel (in vacuo) round the Earth's equator, or in a circle 100 miles above it, with a speed of 4·91 or 4·85 miles per second, in 84·4 or 85·5 minutes, and this was very near the lower one of the two assigned speed limits. But the meteor's course was inclined downwards 36° from horizontal, and could not have come from outside of the small sphere (not sensibly wider than a three or four days' journey of the Earth along its orbit), of the Earth's attraction with any less final speed of penetration into the atmosphere than about 6·9 miles per second, which nearly approached the mean between the chosen limits; for with any less observed final speed than this, the meteor would be kept constantly revolving round the Earth as a satellite, until it should chance to plunge into the atmosphere by lunar and solar perturbations and resisting actions, which actually befell this bolide when it was just at the node of the meteor-train of *Biela's* comet.

Thus the superior speed limit, or somewhere near it, and the second calculated orbit, will probably afford us, it would seem, the only obtainable approximation to this singular pathed meteor's real course about the Sun. But as in this native course the meteor almost overtook the Earth directly, and as the relative or apparent radiant-point was well shown to be near the pole of the

* *British Association Reports*, 1878, p. 270-73, and 1879, p. 84-5 (Mr. Hind's and Professor von Niessl's remarks on the meteor's real path and orbit).

ecliptic (about midway between δ and υ *Draconis*), a considerable increase of the slow observed meteor speed might be admitted without materially affecting the deduced result that the orbits' form was nearly circular, overtaking the Earth very near its perihelion point, at just the node of the *Biela* comet meteors, with a slope of 20° or 25° to the plane of the ecliptic. On the appearance of these results in Colonel Tupman's paper above referred to, on "A Meteor of Short Periodic Time," it was pointed out by Mr. Hind* that excepting in the lengths of period and of major axis, the computed orbit's elements resembled very closely those of *Biela's* comet, which also, at its last appearance in 1852, overtook the Earth at this node with an inclination of about 12°, about 4° before its perihelion. There can be, therefore, little doubt that a large member of the *Biela* meteor-train had in one or two previous passages of the Earth through this meteor-ring been both reduced in speed and made steeper in its orbit's slope, to the ecliptic. But the apparent radiant's displacement through 55° from the usual position in *Andromeda* to near the head of *Draco*, or through nearly 70°, if the zenithal deflection in the observed path (acting at the last return *to just undo* some 12°, at least, of former deflection amounts in that direction) is allowed for, would require for its production not less than three close grazes, all in the same direction, of a *Biela* shooting-star, in front of the earth, each capable *in vacuo*, or unhelped by air-resistance, to bend the meteor's relative course past the earth through a maximum angle of about 24°. As no co-operating air-resistance in the last deflection, which was just opposite in direction to the previous ones' collective sum, can have brought about the large directional displacement, and as again no earth-deflections without the air's resistance could alter the relative speed of about 12 miles per second, with which the diverted *Bielid* would after each grazing passage continue to revisit and to pass through the Earth's attractive sphere again, from time to time, quite unretarded, a suggestion made by Professor von Niessl,† that resistance was the efficient agency in producing both this meteor's slow motion and the slow speed of the aerolitic fireball of 1877 January 12, seems, in this present meteor's case at least, to be very full of significance, as it seems hardly possible to explain, except by air-resistances in previous *rencontres*, how a meteor of even such a slow-moving star-shower as the *Andromedes*, could lose nearly half its relative or earth-regarded meteor-speed, and be deflected nearly 70° in apparent path direction from the well-marked relative radiant-centre of its parent meteor-current.

One more example of slow speed presented itself in a singular-looking bolide seen in south-eastern parts of England (at Worth-

* *Nature*, vol. xix. p. 484, 1879 March, and *British Association Reports*, 1879, *loco sup. cit.*

† *Sitzungsberichte d. k. k. Akademie* (Vienna; *Naturw. Klasse*), Vol. 79, May 8, 1879; and *Brit. Assoc. Reports*, 1879, *loco sup. cit.*

ing and Freshwater, London, Slough, and Tunbridge Wells) at about $9^h\ 15^m$ P.M. on 1898 August 21. As seen at Slough, it had a globular, bright green head nearly as bright as *Venus*, for half its course, which expanded without brightening then, and became kite-like with a short tail and outstretched wings, in length and width about $1\frac{1}{2}° \times \frac{1}{2}°$, and growing paler green or yellow as it moved leisurely, a little inclined downwards, through about 35° in all, in five well-timed seconds, to a point of gradual disappearance 20° or 21° above the horizon nearly due south. The time of flight was judged very satisfactorily, and could not have been more than 0·5 or 1·0 second under- or over-rated. The apparent paths at Worthing and Slough were also well referred to the stars, and the resulting real path was found to be 95 or 100 miles in length, from 61 miles over the coast of France, near the mouth of the Somme, to 21 miles high over a point 36 miles south of Brighton. The real speed was thus 19 or 20 miles per second, while for a parabolic orbit the speed for the real path's radiant point, near γ *Pegasi*, should have been 34 miles per second.

But a note, evidently of the same meteor, by an observer in Oise, in France, referring its path there to the stars, appeared in the *Bulletin de la Société Astronomique de France* of 1898 November (p. 473), which supplies a good control on the real path obtained from the English observations. It appears that the meteor's true course was certainly higher and further south, or more distant than had been computed, from the English stations; while the mean radiant-point, from the three accounts, at 359°, +10°, differs only about 4° from the precise point of intersection, at $2\frac{1}{4}°$, $+12\frac{1}{2}°$, of the paths mapped in England. By redetermining the meteor's real course with the help of the new observation, it appeared that it descended 123 miles in 5 seconds from 87 miles above Montdidier, Somme, in France, to 42 miles above the sea, 60 miles south from Brighton. The observed paths at Slough and Worthing required to be raised and lowered respectively (towards each other), 2°–3°, and 3°–4°, and the observed path in Oise to be kept as distant from them both, as the description given of it there by stars permits, to allow the three tracks to be combined compatibly together; so that it would be hardly possible to reconcile the three well-situated observations, without considerably overestimating the possible errors of the English ones, with greater heights than these (which agree well with the usual beginning and end heights of conspicuous-looking meteors), or with a longer path than 123 miles in 5 seconds, denoting a real speed of about $24\frac{1}{2}$ miles per second. For a parabolic orbit the meteor-speed from the adopted radiant-point should be 32 miles per second, and the utmost allowable range of the duration, between 4 and 6 seconds, would give a real observed speed somewhere between $20\frac{1}{2}$ and 31 miles per second, almost certainly less than the radiant-point's theoretical parabolic speed.*

* See note on page 194.

A succession of meteor-showers from an apparently long enduring and approximately stationary radiant-centre at about 5°, +10° (longitude and latitude about 8°, +7°), has been recorded by several observers almost continuously from July to October ;* and it is with a certain small congeries of four of those showers, very accordantly observed by Col Tupman and Mr. Denning, in 1869–85, close to that mean shower centre (at about 5°, +13°, between August 18 and 25), that this meteor's path direction from about 359°, +10°, or 2°½, +12°½, on August 21, seems certainly, from its close proximity to them, to have been immediately connected. Now, as the apex of the Earth's way was then at about longitude 58°, or about 50° onwards from this long enduring meteor-shower's fixed radiant-point on August 21, and as the apex would recede further and further from this fixed point at later dates, any parabolic streamlet of the common radiant's swarm encountered in September or October would furnish slower meteors then than a similar constituent current of the swarm would do on August 21. But if it could creep back, in node, from the later to the earlier date without any change of either its apparent speed or radiant-point, the slow speed of this small green kite-shaped fireball of 1898 August 21, might then be sufficiently explained by supposing it to have belonged originally (just as in the above noted case of the large aerolitic fireball of 1879 January 12) to a parabolic meteor shower crossing the Earth's orbit on some later date (about 10° or 15° further on in longitude) than the marked shower group to which the bolide seems to have belonged, at 5°+13° on August 18–25. The re-estimated speed of flight, of 24½ miles per second, and the slightly altered radiant-point, corrected for zenithal deflection to 0°, +8½, of the meteor's redetermined real path, gives the following elliptic elements of its short, but very eccentric orbit round the Sun :

Major and Minor Axes . . 2·098 and 0·545,
Aphelion and Perihelion distances, 2·062 „ 0·036.
Eccentricity, 0·9657 ; Motion, direct.
Inclination, 36° ; Anomaly, −15° 35′ ;
☊ 148° 47′ } Period, 392·5 days,
π 133° 12′ } P.p., 1898, October $3^d\ 4^h$.

With either this short elliptic or with a parabolic speed, this August shower-group's meteors approach the Earth's orbit from a real direction in solar space only a few degrees behind, and a few degrees above, or north of the antisolar point ; and the anomaly and perihelion distances of their parabolic paths differ

* Mr. Denning regards this shower as a long enduring stationary one, and has included it as No. 3, at 6°, +11°, July–September, in his "Catalogue of 117 Long enduring, and apparently Stationary Radiant-points of Shooting Stars," in *Astronomische Nachrichten*, No. 3531, 1898 December.

very slightly ($-23°$ and 0·040) from those of the short-period elliptic orbit; so that only the periodic time and major axis of the orbit are greatly changed, in this instance (though the inclination of the parabolic orbit decreases also from 56° to 36°), by imparting to the meteor speed abnormal slowness.

It may be very probably conjectured from these few, nowise isolated or very exceptional, cases of speed determinations, that if all meteors are supposed to have been originally moving in parabolic orbits, some stationary radiant-points have pretty certainly appeared at times to produce meteors moving with velocities of abnormal slowness; and that among such slow-flighted radiant-centres some have also occasionally exhibited good examples of accordance with the node-translational theory's requirements.

In the two cases, only, reviewed above, of the fireballs of 1879 January 12, and 1898 August 21, which afforded such directly good agreements, the stationary radiant-centres happened to lie somewhat behind or westward from the eastward moving apex of the Earth's way; and a consistent explanation of the unusual slowness of those meteors' motions could on that account be easily presented, by supposing their nodes, in bygone times, to have gradually retreated to their now observed places, with fixed radiant-points and with constant meteor-speeds, from some slightly later original points on the ecliptic. For the Earth's apex, in ancient encounter-times, would there be more advanced, and therefore more distant than at the present nodal place, from the fixed radiant-points' directions; so that it would confer upon the meteors at their original ancient shower-dates, slower relative meteor-speeds—afterwards transplanted backwards with the nodes—than correspond parabolically with their present nodes and dates.

But for a slow centre's position in the other semicircle of longitude lying in front or eastward, instead of behind or westward from the Earth's apex, the explanation of slow speed which the node-displacement theory would furnish is considerably less simple; for in that case a node or shower-date anciently a little later, would signify nearer vicinity of the radiant-point to the Earth's apex, instead of greater distance from it, at the ancient, than at the modern encounter-time, or abnormal *enhancement* of the meteor speed by the node's backward journey, which is, of course, incompatible with progressive continuance of the node-displacing action, because a single such enhancement of a meteor's speed, by rendering its orbit hyperbolic, would withdraw the meteor for all future time from the Earth's vicinity. It may be added also, that the same reasoning obviously precludes attempts to attribute to these node-shifting actions any occasionally suspected abnormally swift meteor-motions, like those in the above table of the fireballs of 1877 January 19, and 1898 January 21, and of a few others of the above-noted fireballs, appearing to have had velocities exceeding those properly belonging to parabolic orbits. But, if it is not obligatory to

regard the node's excursion as confined to very moderate, restricted limits, a *still later* old time shower-date may still, in this case also, be always chosen suitable for the node shifting explanation, some measure of lateness *farther* on in its date than *just as far beyond* the time and place of the stationary radiant-point's apical culmination, or conjunction in longitude with the constantly advancing Earth's apex, as the latter is short of reaching the same culmination or conjunction point at the present-time date of the shower's encountering the Earth in the ecliptic. For the meteor speed being slower then by the radiant's greater elongation from the apex, at an ancient node so placed, than any which the shower should have at all the intervening points crossed by the node in its gradual retreat past the apex from its ancient to its modern place, it could never in the whole of that slow journey exceed or even continue to maintain (as it has at first) the shower speed belonging to a parabolic orbit, so that it would never escape from solar space, but would remain subject to the Sun's and Earth's attractions.

The same abated meteor-speed could not, however, be transplanted, either round many or round a single year's whole circuit from any place where the lower velocity is met with, except from some ancient-node place like that just described; because on its way from a remoter half-circle as its starting place, the shower's fixed radiant-point and meteor-speed would have to pass through one or more conjunctions with the Earth's anti-apex, and being swifter in its meteor-flights than stationary shower-speeds there belonging to parabolic orbits, its meteors would be thrown into hyperbolas and would never return again to the Sun's vicinity. In this way the Earth's anti-apex, in the very first circuit of a shower-node's revolution, acts as a stumbling-block in the way of all originally parabolic meteor swarms' nodal translations, which must gradually sift them away from the Sun's attractive influence until only direct moving parabolic or long elliptic meteor showers are left, which will have their perihelia in the Earth's orbit, and inclinations not exceeding 45°; together with a very varied assemblage of stationary showers, consisting mainly of short-period meteors. For it is not known certainly, but only conjectured by proved analogies with comets, that the primitive orbits of ordinary shooting stars in general are approximately parabolic, and it is therefore allowable to suppose that some slow-pathed streams, particularly with radiants near the pole of the ecliptic, would not have their meteor-speeds raised above those for very long ellipses by their radiant-points' approaches to the Earth's anti-apex. The well-known stationary radiant-point at *o Draconis*, for instance, near the pole of the ecliptic, to which Mr. Denning assigns a duration of nearly the whole year, might belong to meteors moving either in nearly parabolic, in moderately long, or in very short elliptic orbits, and the dimensions, form, and inclination of the orbit would in every case, from the radiant-point's proximity to the pole of the ecliptic, undergo no

appreciable alterations by its node's attractive translation round the whole Earth path's circumference. For other long enduring showers in the same polar neighbourhood, orbits of considerable length and eccentricity might thus also be continuously shifted, without acquiring very different new forms and velocities; and it is pointed out by Professor Turner in his paper that, during the prolonged ages, and the thousands of slow returns which a shower-node's journey from conjunction of the apex to that of the anti-apex with its stationary radiant-point would embrace, the retarding action of a resisting medium might hold in check the growing lengths and velocities of the orbits sufficiently to retain any meteor swarms in closed orbits during their radiant-points' passages near the Earth's anti-apex, even if, as for an observed stationary shower near *η Persei*, or for others close to the ecliptic, the parabolic-pathed meteor-speeds range so far as from 12 to 38, or from 10½ to 44½ miles per second. If, perhaps, this resisting medium might be an extensive, rare atmosphere of the Earth itself, like what the "Bielid" fireball of 1877 November 27 seems to have encountered in the case of its reduced speed, and strong, partially neutralised deflections discussed above, the altered form of orbit might then present no hindrance or unsurmounted difficulty, which Professor Turner has regretfully intimated, to this view's acceptance; since the deformed orbit's node would still be in close proximity to the Earth's path, and in the meteor's repeated returns to it, the same retarding effect might be renewed, and the deflections eliminated by the meteor's passages on various sides of the Earth through its rare atmosphere.

I have endeavoured to compare the irregularities of radiation of the Perseid meteor shower with the probable effects of node-translation on the scattered meteor members of its series of showers, and the case presents, I believe, some satisfactory indications of agreement with this kind of node displacement; but from the retrograde orbit's steep inclination, of 80°, the secular disturbance of the node, or shower-date, gradually onwards, has probably been so slow as to be not far from comparable in its amount with the attractive translation backwards of the stray meteors' nodes (about 1° in 3,000 close encounters); so that occasional meteors from all the showers appear unpunctually before their proper shower-nights, intermingling with earlier showers, and lengthening their own chief dates' durations, and thus I have not yet successfully disentangled the complex results. But in its relations to observed velocities of meteors, the very originally suggested theory of node displacement which Professor Turner has advanced, and already largely and lucidly developed in his foregoing paper, seems to be sufficiently verified by the few examples of meteor observations which have been here quoted, and to have received a quite satisfactory general confirmation from these experimental cases. It seems hardly doubtful, also, that this sound and solid theory will hereafter be found to

be frequently in good accordance with the plentiful results of meteor-path determinations, when further and better trials and examinations are made of them by more extensively conducted comparisons of preserved accounts of their velocities and courses.

[P.S. (to p. 189).—The exact place of the French observer's station, near Attichy and Compiègne, in Oise, now kindly communicated to me by the acting secretary, M. G. Armelin, of the French Astronomical Society, really demands a slightly greater correction than that assumed, of the real path, in the above-found direction; and this must enhance somewhat the rather considerable errors which affect the observations. But if in the mist which there prevailed and greatly impeded accuracy of reference to two glimpsed stars in *Pegasus*, the description of the meteor's path at Worthing was perhaps considerably less accurate than the clear sky projections of the track at Attichy in Oise, and at Slough in England, a rather longer, and therefore swifter path than the above computed one, could be calculated, from a radiant-point at about 351°, +6°, or 353°, +7°, for which the parabolic meteor-speeds are only 28½ or 29 miles per second; and the observed and theoretical meteor-speeds may not then have really been very materially at variance.—Note added, 1899 February 28.]

Observations of the Brightness of α Orionis, 1895–1898.

By T. W. Backhouse.

The accompanying table gives the results of observations of the brightness of *α Orionis* made at Sunderland with my naked eye, except where otherwise stated, from the beginning of 1895 to the middle of December 1898. The names of the stars with which *α Orionis* is compared are given at the tops of the columns, the number above each star being its magnitude taken from the Harvard Photometry, but in the case of ruddy stars (marked R), the magnitude is made ·22 mag. fainter, such stars appearing so much fainter to me than to the H.P. observers. Other stars observed are placed in the "Remarks" column. Columns 1 and 2 give the date and time (G.M.T.) of observation. Column 3 gives the relative atmospheric absorption. As the clearness of the atmosphere varies on different occasions, when an observation is made the apparent clearness, or assumed relative absorption, is recorded, being called 1·0 when it appears as clear as it ever is, or is likely to be, at the place of observation; 2·0 when the absorption seems double this, and so on proportionately, there being no superior limit to the scale. The average absorption in magnitude corresponding to the relative absorption is taken from tables computed from observations made since 1884; but if special observations were made on any particular night for the purpose of obtaining the absorption, a certain amount of weight is given them for modifying the average. Column 4 gives the magnitude calculated as equivalent to a difference of 1 step in

brightness. The other columns, with the exception of the last, which is reserved for "Remarks," give the resulting zenithal magnitudes of the stars, computed from the magnitudes in the top line according to their observed relative brightness. The method of comparison is that of Argelander, namely, by "step estimations." The computations are made so as to satisfy the conditions that, while the calculated differences between the stars in the sequence observed are directly proportional to the number of steps between them, the average magnitude of the stars observed at one time, excluding the variable star, or stars, is kept the same as the average of the magnitudes given at the top of the table for the same stars, and also that their average difference from the average is kept the same. The magnitude of *α Orionis* is shown in two columns, those in italics being calculated from the comparison with *Procyon* and *α Tauri* only, both or either, these being likely to give the most correct results, as each additional star in the computation is likely to introduce a fresh personal equation. Magnitudes in parentheses are the assumed magnitudes, and are so given when there are no data for computation. When *α Orionis* is compared with one star only, the step value is assumed, and taken as equal 0·1 mag.

β Orionis was observed, but is not included in the computations on account of its suspected variability.

Observations of the Brightness of

Date.		Time.	Abm.	Step Value.	Assumed Magnitudes.— 0·18 α Aurigæ.	0·19 Vega.	0·25 α Boötis.	0·46 Procyon.
1895.		h m						
Jan. 18	...	9 18	1·1	·065	..	...	..	0·56
18	...	11 8	1·1	·063	...	...	...	(0·46)
30	...	8 30	1·0	...	...	...	.	(0·46)
30	..	10 52½	1·0	·094		...	0·22	0·45
Feb. 4	...	10 18¼	1·0	...	..	..	(0·25)	..
12	..	9 20	2·0	·060				(0·46)
At Tyne Dock Mar. 13		8 50	1·6	·115	..	...	...	(0·46)
16	...	10 24	1·6	·140		.	...	(0·46)
17	...	8 5	1·3	·090	...	...	...	...
21	...	9 43	1·0	·088	..	..	...	0·48
24	...	8 55	1·0	·092	...	...	...	0·48
Oct. 28	...	16 35	2·0	·112	...	...	...	(0·46)
At Great Ayton, Yorkshire, Nov. 16		10 28	1·0	·070	...	...	...	0·41
Dec. 11	...	12 55	1·4	·117	...	...	...	0·47
13	...	15 35¾	1·5	·111	...	...	...	(0·46)
1896.								
Jan. 12	...	8 45	1·05	·071	...	...	...	0·63
15	...	12 22	1·0	·089	..	...	...	0·46
Mar. 1	.	8 35	1·0	·127	..	.	...	(0.46)
6	...	9 22	1·0	·112			...	(0·46)
16	...	8 0	1·0	·109	.		..	(0·46)
Oct. 8	...	11 30	1·1	.		.		...
8	.	11 43½	1·1	·100			.	...
8	..	11 55$\frac{1}{12}$	1·1	·134	..	..	..	...
Nov. 8	.	16 45	1·3	·124		.	.	0·46
13	...	16 16	1·4	·116	...	.	..	(0·46)
14	...	16 15	1·2	·098		.	...	0·40
29	...	9 58	1·05	·091	...	(0·19)	...	...
29	..	12 10	1·05	·103	0·19	...	...	0·44
29	..	14 15	1·05	·086	0·21	...	...	0·42
30	.	9 57	1·3	·150	(0·18)	(0·19)	...	...

α Orionis, 1895–1898.

B α Orionis.		B 1·22 α Tauri.	B 1·34 β Gem.	1·56 α Gem.	1·90 β Tauri.	1·86 γ Orionis.	Remarks.
0·81	*0·82*	1·09	1·35	1·60	1·76	1·94	
..	*0·89*	(1·22)	...	...	...	...	
...	*0·93*	...	...	...	...	...	Step value assumed.
0·81	*0·88*	1·09	1·50	...	...	...	α Boötis low down.
1·37	...	...	...	...	...	...	Moonlight. Observation made with spectacles. α Boötis low down. Stars apparently equal.
...	*1·03*	(1·22)	...	...	...	...	
...	*1·19*	(1·22)	...	...	...	...	
...	*1·28*	(1·22)	...	...	. .	...	
0·96	*1·12*	(1,22)	(1 34)	...	...	...	
1·24	*1·17*	1·30	1·33	1 60	1·79	...	
1·11	*1·08*	1·26	1·33	1·62	1 81	...	
...	*0·70*	(1·22)	...	...	...	...	
0·82	*0·80*	1·21	1·41	...	...	...	Procyon low down.
0·75	*0·77*	1·14	1·43	...	...	...	
...	*0·86*	(1·22)	...	...	...	...	
0·81	*0·71*	1·14	1·45	1·66	1·78	...	
0·92	*0·84*	1·39	...	...	1·73	...	
...	*0·70*	(1·22)	...	...	...	...	
...	*0·76*	(1·22)	...	...	...	...	
...	*0·79*	(1 22)	. .	...	...	...	
...	*0·62*	(1·22)		...	...	...	Step value assumed.
0·80	*0·80*	(1·22)	.	...	(1·90)	...	
0·58	*0·61*	(1 22)		...	(1·90)	...	
0·73	*0·74*	1·21	...	...	1·72	2·03	
...	*0·65*	(1·22)	...	...	...	...	
0·56	*0·62*	1·14	1·50	1·76	1·66	1·88	
0·71	...	(1·22)	...	..	. .	...	
0·46	*0·45*	1·10	1 45	..	...	...	
0 61	*0·69*	1·06	1·50	.	...	...	
0 91	...	...	..	. .	. .		

Assumed Magnitudes.— Date.	Time.	Aben.	Step Value.	0·18 α Aurigæ.	0·10 Vega.	B 0·25 α Boötis.	0·46 Procyon.
1896.	h m						
Dec. 11 ...	13 40	1·2	·087	0·17	...	..	0·47
28 ..	12 25	1·2	·099	...	...	...	(0·46)
1897.							
Jan. 1 ...	12 32	1·1	·075	...	..	−0·64	0·50
25 ...	9 45	1·05	·079	...	...	...	0·46
Feb. 24 ...	7 45	1·0	·086	0·10	...	...	0·54
26 ...	9 40	1·2	·093	...	...	0·20	0·50
Mar. 18 ..	8 50	1·0	...	...	...	...	...
At Northallerton, Mar. 29 ...	8 26	1·1	·091	0·15	...	0·23	0·54
Oct. 10 ...	11 12	1·0	...	...	...	...	...
Nov. 19 ...	16 22	1·0	·130	...	...	...	(0·46)
1898.							
Sept. 23 ...	14 50	1·0	·144	...	...	...	...
Oct. 24 ...	17 15	1·0	·127	...	...	...	(0·46)
Nov. 16 ...	17 7	1·0	·120	...	...	...	(0·46)
21 ...	16 30	1·2	·056	0·00	...	...	0·84
Dec. 7 ...	14 5	1·0	·076	−0·04	...	...	0·71
11 ...	11 5	1·1	·038	0·19	...	...	0·66
12 ...	12 5	1·2	·077	...	...	...	0·57

R α Orionis.		R 1·22 α Tauri.	R 1·34 β Gem.	1·56 α Gem.	1·90 β Tauri.	1·86 γ Orionis.	Remarks.
0·73	*0·74*	1·17	1·37	1·64	1·79	1·90	
...	*0·76*	(1·22)	...	...	...	...	
0·72	*0·71*	1·17	1·41	1·72	1·68	...	α Boötis not used in computation.
0·83	*0·87*	1·14	1·42	...	...	...	
0·84	*0·88*	1·22	...	...	...	...	
0·82	*0·63*	1·13	1·46	1·75	1·69	...	
...	*0·82*	(1·22)	...	...	...	...	Moonlight. Step value assumed.
0·89	*0·81*	1·30	1·39	1·63	1·70	...	
...	*0·44*	(1·22)	...	...	...	...	Bright moonlight. Stars apparently equal.
...	*0·67*	(1·22)	...	...	...	...	Very slight moonlight.
1·35	*1·05*	(1·22)	...	...	(1·90)	...	
...	*0·96*	(1·22)	...	...	...	...	Slight twilight.
...	*1·07*	(1·22)	...	...	...	...	
1·21	*1·05*	1·31	1·48	1·63	1·55	...	Sirius = −1·56.
1·00	*1·06*	1·09	1·43	1·63	1·79	...	α Leonis = 1·50.
0·90	*0·98*	1·03	...	...	...	...	
0·97	*1·05*	1·10	1·43	1·68	1·69	...	

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

Vol. LIX.	February 10, 1899.	No. 5

Sir R. S. Ball, M.A., F.R.S., LL.D., President, in the Chair;

Eugene Michael Antoniadi, Observatoire Flammarion, Juvisy, Seine-et-Oise, France;
John Jepson Atkinson, Cosgrove Priory, Stony Stratford;
William Lee Dickinson, M.D., F.R.C.P., 9 Chesterfield Street, Mayfair, W.;
John James Hall, Observatory Cottage, Datchet Road, Slough, Bucks;
Joseph Larmor, M.A., D.Sc., F.R.S., St. John's College, Cambridge;
John H. Reynolds, 35 Trinity Road, Birchfield, Birmingham;
Charles Almeric Rumsey, B.A., Dulwich College, London, S.E.;
Charles Stevens, 10 Wemyss Road, Blackheath, S.E.;
William Harold Tingey, B.A., F.R.Met. Soc., Rede Court, Rochester, Kent;
Thomas Weir, 56 Parkfield Street, Moss Lane East, Manchester;
Algernon Charles Legge Wilkinson, B.A., Trinity College, Cambridge,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Ernest William Barnes, B.A., Fellow of Trinity College, Cambridge (proposed by E. T. Whittaker);
Samuel Chatwood, Engineer, &c., Broad Oak Park, Worsley, near Manchester (proposed by Alfred H. Fison);
Rev. W. B. K. Francis, Chaplain and Naval Instructor, Royal Navy, H.M.S. *Boscawen*, Portland (proposed by William J. S. Lockyer); and
Windeyer George Lingham, Master Mariner, 1 Caldervale Road, Clapham, S.W. (proposed by Walter F. Gale).

Report of the Council to the Seventy-ninth Annual General Meeting of the Society.

The following table shows the progress and present state of the Society :—

	Compounders	Annual Subscribers	Total Fellows	Associates	Patron	Grand Total
1897 December 31	244	387	631	38	1	670
Since elected	+ 8	+ 22	...	+ 7	...	...
Deceased	− 8	− 6	...	− 1	...	...
Resigned	...	− 11	...	...	...	...
Removals	+ 3	− 3	...	...	...	...
Expelled	...	− 1	...	...	...	...
1898 December 31	247	388	635	44	1	680

Mr. Knobel's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balances, 1898 January 1 :—						
At Bankers'	239	1	9			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	5	9	2			
In hand of Assistant Secretary on Petty Cash Account	0	0	3			
				244	11	2
Dividends on £13,200 Consols, 2¾ per cent. ...	350	18	4			
" £1,250 Metropolitan 3-per-cent. Stock	36	5	0			
" £932 19 0 Metropolitan 2½-per-cent. Stock	22	11	0			
				409	14	4
Received on account of Subscriptions :—						
Arrears	161	14	0			
Annual Contributions for 1898	575	8	0			
" " 1899	4	4	0			
Admission Fees	60	18	0			
First Contributions	36	15	0			
				838	19	0
Composition Fees				231	0	0
Sales of Publications :—						
At Williams and Norgate's, 1897	1	13	1			
At Society's Rooms, 1898	45	1	10			
Sales of Photographs, 1898	23	18	6			
				70	13	5
Income Tax refunded by Commissioners of Inland Revenue				14	2	0
Outstanding Cheques				14	9	6
				£1,823	9	5

Audited and found correct, January 11, 1899.

F. W. Levander,
Richard Inwards,
Thomas Lewis.

Astronomical Society, from 1898 January 1 to December 31.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
" " for assistance in editing Society's Publications ...	50	0	0			
				300	0	0
House Duty	2	12	8			
Fire Insurance	15	19	1			
				18	11	9
Printing, &c., *Monthly Notices*	401	0	8			
" List of Fellows	8	18	0			
" Miscellaneous	21	12	0			
				431	10	8
Reproduction of Photographs				36	18	1
Purchase of Books for Library	20	0	0			
Turnor and Horrox Fund: Purchases for Library	16	11	0			
Binding Books in Library	28	8	0			
				64	19	0
Computation of Ephemerides				10	0	0
Clerk's Wages	52	6	0			
Postage and Telegrams	68	19	2			
Carriage of Parcels	2	3	2			
Stationery (Spottiswoode & Co.)	11	4	8			
Stationery and Office Expenses	8	13	1			
				143	6	1
Expenses of Meetings	20	0	0			
Lantern Expenses	5	14	0			
				25	14	0
House Expenses	60	15	4			
Coals and Gas	48	9	2			
Electric Light Expenses	5	16	10			
Furniture, &c.	50	16	11			
Sundry Fittings and Repairs	19	10	7			
Sundries	4	11	0			
				189	19	10
Illuminating address to Her Majesty				10	10	0
Lee and Jauson Fund Grants	15	0	0			
Gratuity to Gate Porter	5	0	0			
				20	0	0
Deductions on Cheques				0	1	6
Balances, 1898 December 31:—						
At Bankers' as per Pass-book	542	16	3			
Cheques not credited till 1899	6	6	0			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	2	18	2			
In hand of Assistant Secretary on Petty Cash Account	13	6	1			
				565	6	6
Cheques outstanding 1897 December 31				6	12	0
				£1,823	9	5

Report of the Auditors.

We have examined the Treasurer's accounts for the year 1898, and have found and certified the same to be correct. The cash in hand on December 31, 1898, including the balance at the bankers', &c., amounted to £565 6*s*. 6*d*.

The funded property of the Society is the same as at the end of the previous year.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

(Signed) RICHARD INWARDS,
THOMAS LEWIS,
F. W. LEVANDER.

Trust Funds.

The Turnor Fund: A sum of £450 2¾-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Horrox Memorial Fund: A sum of £100 2¾-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Lee and Janson Fund: A sum of £323 16*s*. 6*d*. 2¾-per-cent. Consols, the interest to be given by the Council to the widow or orphan of any deceased Fellow or Associate of the Society who may stand in need of it.

The Hannah Jackson (née Gwilt) Fund: A sum of £300 2¾-per-cent. Consols, the interest to be given in Medals or other awards, in accordance with the terms of the Trust.

Assets and Present Property of the Society, 1899 *January* 1.

	£ s. d.	£ s. d.
Balances, 1898 December 31 :—		
At Bankers', as per Pass-book	542 16 3	
Cheques not credited till 1899	6 6 0	
In hand of Assistant Secretary on account of Turnor and Horrox Fund	2 18 2	
In hand of Assistant Secretary on Petty Cash Account	13 6 1	
	565 6 6	
Less outstanding cheques	14 9 6	
		550 17 0
Due on account of Subscriptions :—		
11 Contributions of 4 years' standing	92 8 0	
6 " 3 "	37 16 0	
31 " 2 "	130 4 0	
65 " 1 "	136 10 0	
2 Admission Fees and First Contributions ...	6 6 0	
	403 4 0	
Less 2 Contributions for 1899 paid in advance	4 4 0	
		399 0 0
Due from Messrs. Williams and Norgate for sales of Publications during 1898		16 3 6

£13,200 2½-per-cent. Consols, including the Lee and Janson Fund, the Turnor and Horrox Fund, and the Jackson-Gwilt Fund.

£1,250 Metropolitan 3-per-cent. Stock.

£932 19 0 Metropolitan 2½-per-cent. Stock.

Astronomical and other Manuscripts, Books, Prints, and Instruments.

Furniture, &c.

Stock of Publications of the Society.

Three Gold Medals.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXX.	147	1
I. Part 2	41	...	XXXI.	134	...
II. Part 1	50	3	XXXII.	145	...
II. Part 2	15	3	XXXIII.	154	...
III. Part 1	64	1	XXXIV.	157	1
III. Part 2	82	1	XXXV.	104	2
IV. Part 1	76	1	XXXVI.	187	8
IV. Part 2	89	3	XXXVII. Part 1	332	7
V.	100	1	XXXVII. Part 2	278	8
VI.	116	6	XXXVIII.	263	1
VII.	140	3	XXXIX. Part 1	228	3
VIII.	124	3	XXXIX. Part 2	233	3
IX.	131	3	XL.	248	...
X.	142	...	XLI.	395	1
XI.	148	...	XLII.	224	3
XII.	155	...	XLIII.	225	...
XIII.	153	...	XLIV.	206	1
XIV.	361	...	XLV.	238	...
XV.	134	...	XLVI.	215	1
XVI.	158	1	XLVII. Part 1	3	...
XVII.	141	1	XLVII. Part 2	18	...
XVIII.	134	1	XLVII. Part 3	2	...
XIX.	144	...	XLVII. Part 4	10	...
XX.	133	1	XLVII. Part 5	8	...
XXI. Part 1	244	...	XLVII. Part 6	9	...
XXI. Part 2	98	...	XLVII.	188	...
XXI. 1 & 2 (together)	55	...	XLVIII. Pt. 1	227	2
XXII.	157	...	XLVIII. Pt. 2	232	1
XXIII.	142	...	XLIX. Part 1	378	1
XXIV.	148	1	XLIX. Part 2	257	...
XXV.	158	...	L.	243	1
XXVI.	163	1	LI.	291	1
XXVII.	417	1	Index to *Memoirs*	619	3
XXVIII.	374	...			
XXIX.	395	1			

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	54	...	XXXI.	91	...
II.	58	...	XXXII.	108	5
III.	...	...	XXXIII.	90	...
IV.	...	...	XXXIV.	68	1
V.	...	...	XXXV.	51	...
VI.	42	—	XXXVI.	26	1
VII.	2	...	XXXVII.	32	3
VIII.	152	2	XXXVIII.	96	2
IX.	24	3	XXXIX.	92	...
X.	171	1	XL.	105	3
XI.	183	...	XLI.	105	5
XII.	105	2	XLII.	113	1
XIII.	177	2	XLIII.	108	2
XIV.	176	[illegible]	XLIV.	112	2
XV.	167	2	XLV.	115	1
XVI.	154	1	XLVI.	110	...
XVII.	165	1	XLVII.	126	2
XVIII.	242	...	XLVIII.	117	...
XIX.	52	...	XLIX.	112	7
XX.	31	...	L.	111	10
XXI.	16	...	LI.	114	[illegible]
XXII.	30	...	LII.	112	11
XXIII.	17	...	LIII.	115	14
XXIV.	22	...	LIV.	115	14
XXV.	13	...	LV.	129	1
XXVI.	9	...	LVI.	121	3
XXVII.	[illegible]	...	LVII.	135	3
XXVIII.	70	...	LVIII.	130	7
XXIX.	50	...	1st Index ...	546	3
XXX.	[illegible]	2	2nd „ ...	844	...

Library Catalogue 545 2

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to LVIII., no complete volumes can be formed from the separate numbers in stock.

Celestial Photographs.

The following is a list of reproductions of Celestial Photographs published by the Royal Astronomical Society for sale to the Fellows :—

R.A.S. Ref. No.	Subject.	Photograph by
1	Total Solar Eclipse, 1889 January 1	W. H. Pickering
2	Total Solar Eclipse, 1893 April 16	J. M. Schaeberle
3	Total Solar Eclipse, 1886 August 29	A. Schuster
4	Nebulæ in the *Pleiades*	Isaac Roberts
5	Nebula M 74 *Piscium*	Isaac Roberts
6	Great Nebula in *Orion*	Isaac Roberts
7	Milky Way near *Messier* 11	E. E. Barnard
8	Milky Way near Cluster in *Perseus*	E. E. Barnard
9	Comet *c* 1893 IV. (Brooks), 1893 October 21	E. E. Barnard
10	Comet *a* 1892 I. (Swift), 1892 April 7	E. E. Barnard
11	Nebula about *η Argûs*	David Gill
12	Portion of Moon (Hyginus-Albategnius)	Lœwy and Puiseux
13	Comet *c* 1893 IV. (Brooks), 1893 October 22	E. E. Barnard
14	Comet *c* 1893 IV. (Brooks), 1893 October 20	E. E. Barnard
15	Comet *c* 1893 IV. (Brooks), 1893 November 10	E. E. Barnard
16	Comet *a* 1892 I. (Swift), 1892 April 16	E. E. Barnard
17	Comet *f* 1892 III. (Holmes), 1892 November 10	E. E. Barnard
18	Comet *a* 1892 I. (Swift), 1892 April 18	E. E. Barnard
19	Portion of Moon (Alps, Apennines, &c.)	Lœwy and Puiseux
20	Nebula in *Andromeda*	Isaac Roberts
21	*Jupiter*, 1892 September 26	Lick Observatory
22	Cluster M 13 *Herculis*	W. E. Wilson
23	Total Solar Eclipse, 1893 April 16 (5 sec. expos.)	J. Kearney
24	Total Solar Eclipse, 1893 April 16 (20 sec. expos.)	J. Kearney
25	The Moon (Age $7^d\ 3^h$)	Lick Observatory
26	The Moon (Age $12^d\ 6\frac{1}{2}^h$)	Lick Observatory
27	The Moon (Age $16^d\ 8^h$)	Lick Observatory
28	The Moon (Age $23^d\ 8^h$)	Lick Observatory
29	The Sun, 1892 February 13	Roy. Obs., Greenwich
30	The Sun, 1892 July 8	Roy. Obs., Greenwich
31	Portion of Moon (Region of *Maginus*)	Lœwy and Puiseux

R.A.S. Ref. No.	Subject.	Photographed by
32	The Moon (Age 14^{d} 8^{h})	Lick Observatory
33	Portion of Moon (Ptolemæus, &c.)	Lick Observatory
34	Portion of Moon (Mare Serenitatis)	Lick Observatory
35	Portion of Moon (Clavius, Licetus, &c.)	Lick Observatory
36	Portion of Moon (Regiomontanus, &c.)	Lick Observatory
37	Portion of Moon (Tycho, Thebit, &c.)	Lick Observatory
38	Portion of Moon (Theophilus, &c.)	Lick Observatory
39	Total Solar Eclipse, 1896 August 9 (3 sec.)	S. Kostinsky
40	Total Solar Eclipse, 1896 August 9 (26 sec.)	A. Hansky
41	Cluster M 56 *Lyræ*	
42	Nebulæ M 81, 82 *Ursæ Majoris*	
43	Cluster M 56 *Lyræ* (enlarged)	
44	Solar Corona, 1871 December 12, Baikul	H. Davis
45	Solar Corona, 1875 April 6, Siam	Lockyer and Schuster
46	Solar Corona, 1878 July 29, Wyoming	W. Harkness
47	Solar Corona, 1882 May 17, Egypt	Abney and Schuster
48	Solar Corona, 1883 May 6, Caroline Island	Lawrence and Woods
49	Solar Corona, 1885 September 9, Wellington, N.Z.	Redford
50	Solar Corona, 1886 August 29, Grenada, W.I.	A. Schuster
51	Solar Corona, 1887 August 19, Japan	M. Sugiyama
52	Solar Corona, 1889 January 1, California	W. H. Pickering
53	Solar Corona, 1889 December 22, Cayenne	J. M. Schaeberle
54	Solar Corona, 1893 April 16, Fundium	J. Kearney
55	Solar Corona, 1893 April 16, Brazil	A. Taylor
56	Great Nebula in *Orion*	W. E. Wilson
57	Dumb-bell Nebula, *Vulpecula*	W. E. Wilson
58	Spiral Nebula, *Canes Venatici*	W. E. Wilson
59	Spiral Nebula, *Canes Venatici* (enlarged)	W. E. Wilson
60	Annular Nebula in *Lyra*	W. E. Wilson
61	Meteor Trail and Comet Brooks, 1893 November 13	E. E. Barnard
62	Total Solar Eclipse, 1898 January 22 (5 sec.)	W. H. M. Christie
63	Total Solar Eclipse, 1898 January 22 (20 sec.)	W. H. M Christie
64	Solar Corona, 1896 August 9, Novaya Zemlya	G. Baden-Powell
65	Solar Corona, 1898 January 22, Pulgaon, India	E. H. Hills
66	Nebula in *Andromeda*	Roy. Obs., Greenwich

Nos. 44–55 and Nos. 64 and 65 form a series of corona photographs, oriented and reduced to the same scale.

The above photographs are now on sale to Fellows as prints,

either platinotype or aristotype, mounted on sunk cut-out mounts, measuring 12 inches by 10 inches, and also as lantern slides. Nos. 44–55 and Nos. 64 and 65 are also supplied as transparencies, $6\frac{1}{4}$ inches square.

Price of prints, 1*s.* 6*d.* each; lantern slides, 1*s.* each; packing and postage extra.

Unmounted prints, 1*s.* each, can be obtained to order.

Transparencies, $6\frac{1}{4}$ inches square (Nos. 44–55 and Nos. 64 and 65), 3*s.* 6*d.* each.

Orders to be addressed to W. H. Wesley, Burlington House, London, W. In ordering prints or slides the R.A.S. Reference No. only need be quoted, but in the case of prints it should be stated whether platinotypes or aristotypes are required.

Instruments belonging to the Society.

A brief description of the chief instruments and other particulars relating to them will be found in *Monthly Notices*, vol. xxxvi. p. 126.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.
„ 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatorial.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatorial.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatorial, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.

No. 25. A sextant, by Bird (formerly belonging to Captain Cook).

„ 26. A globe showing the precession of the equinoxes.

The *Sheepshanks* collection :—

„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.

„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumb-line; portable clamping foot and tripod stand.

„ 29. (3) Equatorial stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.

„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.

„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.

„ 33. (7) 2-foot navy telescope.

„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Y's for fixing to stone piers; two axis levels.

„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, reading to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y-piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator, with object-glass $1\frac{3}{4}$-inch diameter

and 16 inches focal length; stand, rider-level, and fittings.

No. 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25) Ordinary 4½-inch compass with needle.

„ 52. (26) Dipping needle, by Robinson.

„ 53. (27) Compass needle, mounted for variation.

„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.

„ 55. (29) Box of magnetic apparatus.

„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.

„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.

„ 58. (32) Plane 2⅜-inch speculum, artificial horizon and stand.

„ 59. (33) 2½-inch circular level horizon, by Dollond.

„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches; tripod stand.

„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.

„ 62. (36) A pantograph.

„ 63. (37) A noddy.

„ 64. (38) A small Galilean telescope with object-glass of rock crystal.

„ 65. (39) Five levels.

„ 66. (40) 18-inch celestial globe.

[illegible] stand for telescope.

[illegible], with object-glass of rock crystal.

No. 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. $9\frac{1}{4}$-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double-image micrometer, by Troughton and Simms.
„ 86. $4\frac{1}{2}$-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.
„ 87. $3\frac{1}{4}$-inch Gregorian reflecting telescope with wooden tripod stand.
„ 88. Pendulum, with 5-foot brass suspension rod, working on knife-edges, by Thomas Jones.
„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
„ 90. An Arabic celestial globe of bronze, $5\frac{3}{4}$ inches in diameter.
„ 91. Astronomical time watch-case, by Professor Chevallier.
„ 92. 2-foot protractor, with two movable arms, and vernier.
„ 93. Beam compass, in box.
„ 94. 2-foot navigation scale.
„ 95. Stand for testing measures of length.
„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position angles.
„ 97. 12-cell Leclanché battery.
„ 98. 2-foot 6-inch navy telescope, with object glass $2\frac{1}{2}$ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer and Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatorial sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial.
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.

No. 107. Compass, by C. Earle, Melbourne.
" 108. Prismatic compass, by Negretti and Zambra.
" 109. Dipleidoscope, by E. Dent.
" 110. Abney level, by Elliott.
" 111. Pocket spectroscope, by Browning.
" 112. Universal sun-dial.
" 113. Double sextant, by Jones.
" 114. Two models, illustrating the effects of circular motions.
" 115. A cometarium.
" 117. Two old sun-dials.
" 118. A 10½-inch sixteenth-century celestial globe, on bronze tripod stand.
" 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
" 120. A 6-prism spectroscope, by Browning.
" 121. Spitta's improved maximum and minimum thermometer.
" 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
" 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
" 124. Position micrometer, by Cooke.
" 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
" 126. 3½-inch portable refracting telescope, by Tulley, with tripod stand.
" 127. Globe representing the visible surface of the Moon, by John Russell, R.A. (1797).
" 128. Bichromate battery and Ruhmkorff coil.
" 129. Slater's improved armillary sphere.
" 130. 10-inch brass pillar sextant with counterpoise stand, by Troughton.
" 131. Double box sextant, by Cary.
" 132. Equatorially mounted camera with 2½-inch portrait lens and telephotographic enlarging lens by Dallmeyer; iron pillar. [Presented by the executors of the late Sidney Waters.]
" 133. 3¼-inch equatorial by Ross, with tall tripod stand, equatorial mounting, eyepieces, and micrometer. [Presented by Mrs. Mann.]
" 134. Old transit instrument, 2-inch aperture and 3-feet focal length, formerly belonging to Dr. Longfield, of Cork. [Presented by the executors of the late R. J. Lecky.]
" 135. Globe of Mars, by E. M. Antoniadi. [Presented by M. Antoniadi.]

Besides the above, there is the following apparatus available for eclipse work:—

4 Slits for spectroscope.
2 Abney lenses used in photographing the corona.
2 Dallmeyer negative enlarging lenses.
1 Cœlostat with 16-inch plane mirror.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 16. The *Wollaston* telescope, to Mr. R. Inwards.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 27. (1) 30-inch transit and stand, to Mr. B. T. Moore.
„ 28. (2) 6-inch theodolite and stand, to Dr. A. A. Common.
„ 29. (3) Equatorial mounting, clock, &c., to the Rev. C. D. P. Davies.
„ „ Wire micrometer (No. 2), to the Rev. C. D. P. Davies.
„ 30. (4) $3\frac{1}{4}$-inch equatorial and stand, to Mr. C. H. Johns.
„ „ Double-image micrometer, to the Rev. W. J. B. Roome.
„ 39. (13) Horizon, roof, and mercury bottle, to Mr. W. H. Finlay.
„ 42. (16) Artificial horizon, roof, and mercury bottle, to Mr. F. Robbins.
„ 50. (24) Prismatic compass, to Mr. Maxwell Hall.
„ 57. (31) Box sextant, to Dr. A. A. Common.
„ 69. (43) Telescope with rock-crystal object glass, to Sir W. Huggins.
„ 72. (*c*) Polarimeter, to Professor C. Michie Smith.
„ 74. Registering spectroscope, to Mr. W. Shackleton.
„ 76. (*b*) 5-prism direct-vision hand spectroscope, to Mr. E. W. Ellerbeck.
„ 78. $9\frac{1}{4}$-inch reflector and stand, to the Rev. W. J. B. Roome.
„ 98. 2-ft. 6-in. navy telescope, to the Rev. J. M. Bacon.
„ 119. Diffraction gratings, to Mr. B. T. Moore.
„ 123. 6-inch telescope, by Grubb (object-glass only), to Mr. W. E. Wilson.
„ 125. 6-inch refractor by Simms, to Dr. A. A. Common.
„ 128. Bichromate battery, to the Rev. W. J. B. Roome.
„ 130. 10-inch brass pillar sextant, by Troughton, to Mr. F. Robbins.
„ 131. Double sextant, by Cary, to Mr. W. H. Finlay.
„ 132. The *Waters* equatorial, to Mr. E. W. Maunder.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Mr. Frank McClean, for his photographic survey of star spectra in both hemispheres, and other contributions to the advancement of astronomy.

The Library.

A supplementary catalogue, containing the additions to the library from 1884 June to 1898 June, is in preparation and will shortly be published.

OBITUARY.

The Council regret that they have to announce the loss by death of the following Fellows and Associates during the past year :—

Fellows :—J. G. Barclay.
L. H. Bradford.
Latimer Clark.
Edwin Dunkin.
John Hippisley.
W. B. Hutchinson.
Henry Perigal.
Rev. T. J. Potter.
Rev. Bartholomew Price.
Herbert Sadler.
A. F. Smith.
J. E. de Villiers.
George Williams.
Rev. A. Wrigley.

Associate :—Cyrille Souillart.

JOSEPH GURNEY BARCLAY, who was born in 1816, was the son of Robert and Elizabeth (*née* Gurney) Barclay, in direct descent from Colonel Barclay (1610), who purchased the Urie Estate, and from his son, Robert Barclay, author of the "Apology." When J. G. Barclay was a boy, his father purchased and went to live at Knott's Green, Leyton, which has since been a family residence of the Barclays. For more than fifty years J. G. Barclay was a partner (in later years the head) of the well-known banking firm of Barclay, Bevan & Co. ; he retired from the firm on its amalgamation with a number of other banks and conversion into a limited company in 1896. He twice married, his first wife being Mary Walker Leatham, of the well-known Yorkshire family, by whom he had two sons and one daughter, of whom only one, Robert Barclay, is now living. On his marriage he took up his residence at the Limes, Walthamstow, coming into possession of Knott's Green on his father's death. His second wife, Margaret Exton, of Hitchin, survives him, together with her three sons and two daughters. Mr. Barclay was a Quaker. He read a great deal both of scientific and ordinary books up to within a few years of his death, and never lost his powers of taking interest in what

was going on round him. He died 1898 April 25, at Exton House, Brighton, in his 82nd year.

Mr. Barclay began to take an interest in astronomical work some time before 1854, as he tells us in the Introduction to the *Leyton Observations*, vol. i. In the autumn of 1854 he set up an Observatory with 7½-inch equatorial by Cooke, and transit circle by Troughton & Simms. He scrutinised *Procyon* for a companion which might explain its irregular proper motion, and detected a wide (45″) faint (10·5) companion, which was not however measured till eight years afterwards. He made drawings of the planets, observed partial eclipses, and did similar astronomical work. He was elected a Fellow of this Society 1855 December 14.

In 1860 the 7½-inch was exchanged for a 10-inch by the same makers, and "the possession of this fine instrument soon taught him the necessity of having someone fully competent to carry on a regular series of observations and reductions." He thus secured the services, as assistant, first of Hermann Romberg, who, however, very shortly left for Berlin and then for Pulkowa (he died 1898 July 6, less than three months after Mr. Barclay); and then of Mr. Talmage, who was continuously in charge of the Observatory from 1865 till his death in 1886.

On the appointment of a regular observer, the work of the observatory settled down into a regular routine, chiefly of double-star observations, though in the first two years Romberg observed some minor planets and comets. Four volumes of *Leyton Observations* were published (size of page 11 in. × 8½ in.; No. of pages, vol. i. 120, ii. 140, iii. 42, iv. 140), and a fifth was promised (*Monthly Notices*, xlv., p. 231), but has not yet appeared. On Mr. Talmage's death the observatory was discontinued, the equatorial being presented to the Radcliffe Observatory, Oxford, and the transit circle to the University Observatory, Oxford.

In the introductions to these volumes a brief description of the observatory and instruments is given. The following remarks about the dome are worth recalling:—

". . . A wooden dome, covered with copper and lined with American cloth, which I found prevented the internal condensation of vapour." (Vol. i., date 1865.)

"Several gentlemen who are building observatories have visited Leyton for the purpose of inspecting the dome, the arrangements of which continue to give perfect satisfaction." (R.A.S. report, 1876 February.)

Latimer Clark was born at Great Marlow, Bucks, 1822 March 10. He originally studied chemistry, and was manufacturing chemist in a large establishment in Dublin; but the activity in railway construction had too great a fascination for him, and in 1847 he commenced railway surveying under his brother, Edwin Clark (who was also a Fellow of this Society, and died in 1894). The latter was soon appointed Superintending Engineer for the Britannia Tubular Bridge across the Menai

Strait, under Robert Stephenson, and Latimer became his assistant (1848-1850). During this period he almost miraculously escaped being crushed to pieces when the tube accidentally fell: his body was compressed into a narrow recess in iron which shielded him from injury, but buttons and portions of his clothing were flattened to the thinness of gold leaf. He afterwards published a description of the bridges, which has run through several editions as a guide book.

During this work at the Menai Bridge Mr. Latimer Clark used to fire a time gun at 8 o'clock by electricity, a circumstance which attracted the notice of Mr. J. L. Ricardo, Chairman of the Electric Telegraph Company, and Mr. Clark was offered, in 1850, the position of Assistant-Engineer in the Company under his brother. Three years later he succeeded his brother as Engineer-in-Chief, and held this position till 1861; and he was then Consulting Engineer till 1870, when the Government took over the business. From 1862 he was Engineer to the Indian Government, and returning from some work in the Persian Gulf he had the misfortune to be shipwrecked, and only his great physical strength enabled him to swim ashore with a dislocated shoulder. With Mr. Forde and Mr. Herbert Taylor he formed a firm of consulting engineers, which has taken part in most of the important cable-laying operations of recent years.

The work of a busy and successful engineer is full of interest for almost any one, but the details, except those specially connected with Astronomy, would be here somewhat out of place. It may be briefly mentioned, however, that Mr. Clark, in 1853-6, introduced the insulation of underground wires by a solution outside the gutta-percha; he first proposed and applied the pneumatic system of conveying letters, parcels, or telegrams, now so extensively used: he invented the inverted double-cup earthenware insulator. From some experiments in conjunction with the late Sir Charles Bright was evolved "Clark's Compound," whereby the life of a cable has been increased five-fold; he improved the earlier designs of his brother Edwin for hydraulic docks, and thus introduced the single and double-walled docks, of which 40 have been built since 1872 for all parts of the world. These are a few only of his many engineering exploits. But he did a great deal of purely scientific work. In the fifties he conducted a long series of experiments on submarine and subterranean wires, showing that the rate of flow of the current was constant, irrespective of the electromotive force. Faraday was much interested in these experimental results, which confirmed his anticipations in a remarkable way. He gave a lecture on Mr. Clark's experiments to the Royal Institution. (See *Proc. R. Inst.* for 1854 Jan. 20; also Faraday's *Experimental Researches*, vol. iii. pp. 508-520.) Mr. Clark also took an important share in the development of the time signal system, though not quite at the beginning. It appears from MS. records that the idea was first started by Airy, and carried into practice by Airy and Edwin Clark working together: but Edwin Clark retired from the

Electric Telegraph Company as above mentioned, when the system was established, and when Latimer succeeded him he took up the subject of time signals enthusiastically, and gave much assistance in extending it, *e.g.* to regulation of the Post Office clocks, Westminster clock, longitude operations, &c. The Post Office clock regulation (*i.e.* the mechanical correction of clocks by hourly signal) was after some years discontinued.

About the same time Mr. Clark was the means of having magnetic observatories furnished with wires for the observation of Earth currents.

In 1882 he introduced his little transit instrument, illustrated and described in an octavo volume, *A Treatise on the Transit Instrument as Applied to the Determination of Time, for the use of Country Gentlemen.* "The motive of this little work," he said in the preface, "is a desire to introduce the transit instrument into more common use for purposes of utility and amusement. . . . The writer believes that if this charming instrument were more fully known it would become as popular as the stereoscope or the camera ; and the object is to show that it may be easily employed by amateurs or others who have not the slightest pretence to scientific knowledge." He also published a *Manual of the Transit Instrument*, 1882, *Transit Tables* annually from 1884 to 1888, and in 1886, in conjunction with the late H. Sadler, F.R.A.S., the *Star Guide*, a useful work of general reference. Mr. Clark's accuracy and clearness made him specially fitted for compiling works of reference. His *Dictionary of Metric and other Useful Measures* appeared eight years ago, and no errors, or practically none, have since been found in it. He collected a very fine library, specially rich in electrical science (he left 4,000 volumes and 2,500 pamphlets dealing with electricity, some of them of great value).

Mr. Clark was President of the Society of Telegraph Engineers (which has since become the Institution of Electrical Engineers) in the fourth year of its existence—1875. He became a member of the Institution of Civil Engineers in 1858, a Fellow of the Royal Geographical Society in 1862, of this Society in 1874, and he was also a member of other societies and institutions. He twice married, in 1855 and in 1863. By the first marriage he had two sons, of whom the elder is an engineer, and the younger, after serving in the 5th Northumberland Fusiliers, is now in the Government Land Office at Adelaide. The second Mrs. Clark survives, but there were no children by the second marriage.

Mr. Clark died suddenly on Sunday, 1898 October 30.

Edwin Dunkin was born on 1821 August 19, at Truro in Cornwall. He was the third son of William Dunkin, who was one of the computers of the *Nautical Almanac.* In those days the *Nautical Almanac* had no local habitation, and those engaged in its reductions could live where they pleased, and used to send their

computations to the comparer by post or mail-coach. It was not till 1832 that, in conformity with a resolution of the council of the Royal Astronomical Society, passed in 1830 November, which had been approved and sanctioned by the Lords Commissioners of the Admiralty, Lieutenant Stratford organised an office in London for the staff of the *Nautical Almanac* The advent of this member of the family is duly chronicled in the minutes of the Board of Longitude (which office was at that time responsible for the expenses incurred by the reductions of the *Nautical Almanac*), as his father seized the opportunity of his arrival to write to the secretary and remind him that there were several months' arrears of salary due to him, the payment of which would be particularly acceptable at the present moment. For the first few years of his life the young Dunkin was educated at private schools in Truro, and, in his daily journeys to and fro, used to pass the Royal Institution of Cornwall, "never dreaming," as he used to say, "that after the lapse of over half a century he should one day return to his native town to deliver the annual address as its president." On the removal of his father to London, in 1832, to join the newly established office of the *Nautical Almanac* in London, he went to school in the neighbourhood of Camden Town, first to Grove House, and then to Wellington House, Hampstead Road, where Charles Dickens had been a scholar a year or two before. In 1837 he was sent to a school at Guines, near Calais, where he still was when his father died in the summer of 1838. As his two elder brothers had predeceased their father, he was left the eldest of the family, and *res angusta domi* necessitated his leaving school and finding something to do to make his own living. So it was that through the influence of his father's old friend, Mr. Davies Gilbert, M.P., F.R.S., and the help of Lieutenant Stratford, Edwin and his younger brother Richard were taken by Mr. Airy, the Astronomer Royal, as two of a staff he was getting together to reduce the planetary and lunar observations of Bradley, Bliss, Maskelyne, and Pond. The severity of this work has often been referred to by Mr. Dunkin; from eight o'clock in the morning till eight o'clock at night were they kept at work, with only one hour's interval, and so strict was the supervision that they might not even munch a biscuit. In the year 1840 Mr. Airy formed the Magnetic and Meteorological Department of the Royal Observatory, under Mr. James Glaisher, and Mr. Dunkin with J. R. Hind (afterwards the head of the *Nautical Almanac* office) was transferred to the observatory staff. Though this work was no sinecure, for there was not as yet such a thing as photographic registration, and therefore eye observations of the magnetic needles had to be made every two hours, day and night; yet the change was felt as a welcome relief to twelve hours' strictly supervised stool work at planetary reductions. In 1845 Mr. Dunkin was transferred to the astronomical department, and became a regular observer with the meridian instruments. His punctual and punctilious

performance of all the duties entrusted to him, and his dexterity as a computer, had thoroughly secured Mr. Airy's interest. The first appearance of his name in the Greenwich volume, he was fond of saying, caused him as pleasurable sensations as any he experienced in his life, and, taken generally, he looked back upon his years of observing as ones which produced for him the most healthful and happiest period of his life. It was about this time he was offered the position of astronomer on the scientific expedition of H.M.S. Beagle, but, as he was looking forward to matrimony, he preferred to remain where he was. In 1847, on the erection of the altazimuth, Mr. Dunkin was put in charge of the instrument and reductions, with one computer, Hugh Breen. For some years these two alone worked this instrument, and took turns of half a lunation at a time, observing the Moon every night that it was visible—an arrangement which must have entailed many an anxious watch. On the occasion of a total eclipse of the Sun in 1851 July, Mr. Dunkin was selected by Mr. Airy to be a member of the official party which went to Christiania to observe this phenomenon, and his account of his observations formed his first contribution to the *Monthly Notices*. In those days the interest of a solar eclipse was concentrated in the study of "Baily's Beads," and as to whether the prominences belonged to the Sun or Moon, and it is curious to recall the fact that Mr. Dunkin, after watching a prominence for over a minute during the eclipse, was inclined to the conclusion that prominences had some connection with the Moon, though he admitted that he might be wrong. In 1853 Mr. Airy and M. Quetelet arranged a preliminary plan of operations for the purpose of determining by telegraph the longitude between Greenwich and Brussels. In accordance with this plan, Mr. Dunkin, as representative of Greenwich, and M. Bouvy, as representative of Brussels, conducted a most successful series of observations. So successful had been this experimental determination that in the following year M. Le Verrier, the head of the Paris Observatory, wished that the operation should be repeated between Greenwich and Paris, and, therefore, as soon as he had taken up his residence at the observatory, one of his first actions was to accept Airy's proposition for a telegraphic determination of longitude between the two observatories made two years previously to Le Verrier's predecessor, Arago, and which, for various reasons, had not yet been carried into effect. Again Mr. Dunkin represented the Greenwich Observatory, while the Paris Observatory was represented by M. Faye, and the operations were carried through with a completeness and accuracy unknown in former operations. In 1854 Airy planned an elaborate series of observations for the purpose of ascertaining the weight of the Earth. The place chosen for this series of pendulum experiments was the Harton coal pit near South Shields. Two invariable pendulums were used, one of which was mounted in a building on the surface, and the other almost vertically 1,260 feet below. For three weeks, under Mr. Dunkin's directions, six

observers continuously observed the swings of these pendulums from Monday morning to Friday evening, and during these three weeks no untoward occurrence interrupted the observations; but on the day after the instruments had been removed an accident occurred in the shaft to some of the lifting apparatus, which, had it happened during the observations, might have injuriously affected the result.

In 1862 Mr. Dunkin was again employed in the determination of telegraphic longitude, this time of Valentia in Ireland. It was during this expedition that Mr. Dunkin discovered the difficulty of keeping a seat in an Irish car when both hands are busy in carefully nursing delicate astronomical instruments. In 1870 Mr. Dunkin was made superintendent of computers, and relieved from all night work. In 1876 he was elected a Fellow of the Royal Society, and from 1879 to 1881 served on the Council. On the resignation of Sir George Airy as Astronomer Royal, his successor, Mr. Christie, recommended Mr. Dunkin for the vacant post of Chief Assistant, and the Admiralty thereupon appointed him to the post for three years only, on account of the superannuation regulations, so that Mr. Dunkin's official connection with the Observatory terminated in 1884 August, at the age of sixty-three, after a service of forty-six years, since when he has not taken a very active part in astronomical affairs. In 1890 and 1891 he served as President of the Royal Institution of Cornwall, and delivered at Truro two presidential addresses on the subject of Astronomy, the first dealing with the influence of the spectroscope and photography on the science, and the second with recent advances in the science generally.

Mr. Dunkin joined the Royal Astronomical Society in 1845, and at the time of his death was the fourth oldest Fellow on our list. For many years he contributed various papers of more or less interest to the *Monthly Notices*. His most important work was a paper, modelled on a similar one by Airy, discussing the solar motion in space from the proper motions of 1,167 stars, and printed in the *Memoirs*. He became a member of the Council in 1868, and in 1870 he was elected Secretary, which position he held for seven years. During his period of office the Society moved its quarters from Somerset House to its present abode at Burlington House, and the trouble entailed by removal fell chiefly on his shoulders. In 1884 he was elected President of the Society, and delivered the usual addresses on the presentation of the medal to Dr., now Sir W. Huggins, and of a joint medal to Professor Pritchard and Professor Pickering, which was the first occasion on which a bye-law passed in 1871 for recognising independent work on the same lines had been carried into effect. Latterly Mr. Dunkin attended the meetings of the Society only occasionally, as he found the journey from town late at night too fatiguing.

Mr. Dunkin took a share in an endeavour to popularise

astronomy and meet the requirements of an educated and inquiring age. Mr. Dunkin re-arranged and brought up to date a new edition of Dr. Lardner's *Handbook of Astronomy*, and wrote the well-known work, *The Midnight Sky*, which contains maps and diagrams, with the names of the principal stars visible from London for each month of the year, besides a general description of the heavenly bodies. He also wrote a book of obituary notices of astronomers, which contains twenty-four biographical sketches of astronomers, mostly written for the *Annual Report of the Royal Astronomical Society*. Besides these books, Mr. Dunkin contributed many miscellaneous papers to the *Leisure Hour* and other periodicals.

Mr. Dunkin enjoyed his well-earned pension for fourteen years, and died on 1898 November 26 at his residence, Kenwyn, Kidbrook Park Road, Blackheath, after a short illness. He married on 1848 April 4 Maria, eldest daughter of the late Samuel Joseph Hadlow, formerly a member of the Stock Exchange. His wife and an only son survive him.

Mr. Dunkin was a man who never affected to array himself with scientific qualifications which nature did not intend him to wear, but liked to describe himself as "a practical astronomer of forty years' standing," and as such he will be remembered.

W. G. T.

John Hippisley, eldest son of the late Rev. Henry Hippisley, was born at Lamborne Place, Berkshire, 1804 October 29. He was educated at Rugby under Dr. Wooll, and at Oriel College, Oxford. He graduated in 1825, taking a second class in both classics and mathematics. He twice married; first in 1831 to Anne Elizabeth Clare, by whom he had three sons and two daughters, of which family three survive; and secondly in 1843 to Georgiana Dolphin, by whom he had two sons and two daughters, of which family also three survive.

Mr. Hippisley possessed considerable mechanical ability, and was devoted to astronomy. He built an observatory at Ston Easton Park, and constructed an excellent reflecting telescope there, casting and grinding its 9-inch speculum with his own hands, and making the body of the telescope, and also the driving-clock, himself. He also personally designed and constructed the machine by which he ground and figured his speculum, and made many other machines and models not so closely connected with astronomy. He was also an artist of much talent, and continued to paint in oils till quite recently. In *Mem. R.A.S.*, Vol. xxiii. p. 56, Lassell mentions an oil painting of the Orion Nebula, made by Mr. Hippisley under Lassell's superintendence from his original sketches. The painting was presented to the Society, and now hangs in the meeting room. It closely resembles the plate accompanying the paper referred to.

Early volumes of the *Monthly Notices* contain six papers from his pen. In vol. xiv. he describes a 'Remarkable Appearance of

the Shadow of Saturn' on the rings, giving an appearance as though the inner ring were raised above the outer ring. He mentions in this paper that his speculum had been lately refigured for him by Mr. Lassell. In a later paper he describes how he again so observed *Saturn* at Mr. Dawes' observatory; though Mr. Dawes and Mr. Lassell, who were present, could not confirm the observation. In 1856 Mr. Hippisley records an observation of *Antares* as a double star, in the "half-hour after sunset," and an occultation of *Jupiter*; and relates how he reproduced the phenomenon known as "projection" of a bright star on the Moon's limb, by means of a mechanical model, showing it to be purely optical. In 1867 he published a rather more ambitious paper on the "Compatibility of the Retrograde Orbit of the November Meteors with the Nebular Theory," and this was his last contribution to our *Notices*.

He was elected a Fellow 1849 December 14, and at the beginning of this year was seventh in order of seniority of our Fellows. He was also a Fellow of the Royal Society. He died at his Bath residence 1898 April 4, in his 94th year, and was buried at Bathwick cemetery.

William Benjamin Hutchinson was the only son of Richard Hutchinson, a consulting engineer in London. He was born in London in 1863, and died from the rupture of a cerebral blood-vessel at Southport, 1898 April 20, at the early age of thirty-five, leaving a widow, a son ten years old, and an infant daughter (since deceased) He was educated at Eton and became an engineer. In the early part of his life he spent some years travelling abroad, on one occasion taking part in an expedition across Central Africa. From 1884 to 1894 he resided at "The Observatory," Liversedge, Yorkshire; from 1894 to the time of his death at Southport.

In his observatory at Liversedge he had a 6-inch refractor by Grubb, and a 5½-inch and 3-inch transit by Cooke. He observed chiefly the Moon and *Saturn*. He was an expert in the construction and mechanism of astronomical instruments, including the grinding of mirrors and lenses.

He was elected a Fellow of this Society 1888 January 13. He was also a member of the Liverpool Astronomical Society, of which he was President in 1890–1891; and a member of various other learned societies. He married in 1887.

Henry Perigal was born 1801 April 1. He was the eldest of six children, the youngest of whom, Mr. Frederick Perigal, is now in his 87th year. He came of a long-lived family, his father, who reached the age of 99 years, being one of thirteen children, nine of whom attained a great age. He traced his ancestry back to Sigurd the Dane, who in 908 made a successful raid on Normandy, assumed the name of Perigal, and settled in France. The English branch of the family sprang from Gideon Perigal

and his wife, Madeline Duval of Dieppe, Huguenots who escaped to London. Henry Perigal belongs to the tenth generation of their descendants. He was remarkably vigorous until the last few years, and it may be recorded that on the occasion of the 90th birthday of Sir G. B. Airy (1891 July 27)—which was celebrated on Saturday, July 25, by a reception at the White House, Greenwich Park—Mr Perigal walked up the steep Croom's Hill to the reception without apparently the least distress, being himself a year older than the distinguished nonagenarian. During the last year or two, however, his strength had failed, and he died peacefully on 1898 June 6.

In early life he was a clerk in the Privy Council office, but, being pensioned somewhat early, joined Mr. Tudor, a family connection, in his stockbroking business. With the greatest regularity he spent, for many years, his days in the office in Threadneedle Street, and his evenings at some scientific meeting, and his venerable figure was familiar at many scientific societies. He was treasurer of the Royal Meteorological Society for nearly fifty years, the fortieth anniversary being celebrated by a dinner given in his honour 1893 April 15 He was also a member of the Mathematical Society, the Microscopical Society, and the Royal Institution. Concerning this last it is interesting to note that, though he attended the Friday evening lectures with great regularity, it was only as a visitor until 1895, when he celebrated his *ninety-fourth birthday* by becoming a member of the Institution. One might search in vain the records of any other society for mention of a candidate in his tenth decade.

He was elected a Fellow of this Society on 1850 February 8, but our publications contain nothing from his pen. His astronomical opinions were indeed conspicuous for their heterodoxy, and it is a remarkable tribute to his personal character that, in spite of such opinions, he was the friend of men whose official positions led them to regard paradoxers generally with special disfavour. De Morgan has recorded in his *Budget of Paradoxes* what trouble these eccentric opinions have cost him; but he was indebted to Mr. Perigal for friendly help in making diagrams. In the records at the Royal Observatory there are bundles of letters from circle squarers and others, which show how little reason the late Astronomer Royal can have had to regard the writers with affection (though he always answered them courteously), yet he was no less glad to see Mr. Perigal at his ninetieth birthday celebration than was the latter to come. And it was always a pleasure to see Mr. Perigal at the dinners of the Royal Astronomical Society Club—an inner circle of the Society not usually mentioned in this official report; perhaps an exception may be pardoned for the purpose of recording the fact that he was elected on 1853 June 17, fifteen years before Mr. Dunkin, who was the next oldest member; his proposer being De Morgan. Such facts as these are sufficient to show the remarkable way in which the charm of Mr. Perigal's personality won him a place

which might have seemed impossible of attainment for a man of his views; for there is no masking the fact that he was a paradoxer pure and simple, his main conviction being that the Moon did not rotate, and his main astronomical aim in life being to convince others, and especially young men not hardened in the opposite belief, of their grave error. To this end he made diagrams, constructed models, and wrote poems; bearing with heroic cheerfulness the continual disappointment of finding none of them of any avail. He has, however, done excellent work apart from this unfortunate misunderstanding. He was an excellent lathe-worker; he has written on the geometry of lathe-work, on the laws of motion, on the methods by which the Pyramids were built, on harmonic motion, cycloidal curves, &c. He never married, but leaves a large number of nephews and nieces.

The Rev. Bartholomew Price was born at Coln St. Dennis, Gloucestershire, 1818. He was educated privately, and at Pembroke College, Oxford, obtaining a first class in mathematics in 1840, the year when at Cambridge Leslie Ellis was Senior Wrangler, to be followed in the next three years by Stokes, Cayley, and Adams successively. Price gained the University Mathematical Scholarship in 1842, and two years later was elected Fellow of his college. In 1844 he became tutor, and ten years later Sedleian Professor of Natural Philosophy. In 1852 appeared the first volume of his elaborate work on the Infinitesimal Calculus; the fourth and last was not published until ten years later. At this time he was doing the greater part of the mathematical teaching in the University, and he was examiner eleven times in twenty-four years. But in 1868 he became Secretary to the University Press, and his success in that capacity was so great that he became gradually absorbed in this new sphere of usefulness. He practically made the Press what it is, increasing its business and its income enormously, and it is for this work that he will perhaps be chiefly remembered. As time went on the affairs of the University passed more and more into his hands, and he became a member of nearly every Board or Council of importance in or representing the University. "The long yet crowded paragraph which announces the death of the late Master of Pembroke in the *University Gazette*," writes one who knew him well, in the *Oxford Magazine*, "is his best epitaph; at once the most eloquent description of his life, and the best measure of what Oxford, what the country, what Church and State, Science and Education, have lost in losing him."

The paragraph is as follows:

"Died, on Thursday, December 29, 1898, at his lodgings in the college, Bartholomew Price, D.D., F.R.S., F.R.A.S., Master of the college, Honorary Fellow of Queen's College, Fellow of Winchester College, Sedleian Professor of Natural Philosophy 1853–1898. Secretary to the Delegates of the University Press

1868–1884, Member of the Hebdomadal Council 1855–1898, Curator of the University Chest, Curator of the Bodleian Library, Perpetual Delegate of the University Press, Delegate of the University Museum. Aged 80."

These, after all, are only some of his distinctions; for instance, his appointment to the Mastership of Pembroke (made by the Chancellor of the University, Lord Salisbury, in his capacity of Visitor of the College, when the Fellows failed to decide between rival candidates) carried with it a Canonry at Gloucester, where Professor Price found time to reside for three months in each year, during the Long Vacation. And again, what is of more interest to us, he was nominated by the Royal Society in 1865 to serve as one of its six representatives on the Board of Visitors of the Royal Observatory, Greenwich, and regularly attended the meetings of the Board up to last June. When the Oxford University Observatory was founded in 1874 Professor Price was put on the Board of Visitors as a matter of course; and it was characteristic of him that he, with the Junior Proctor of the year, audited the observatory accounts from the first, and continued to do so until his death. In 1878, when a committee of three was appointed to consider the outstanding requirements of the new observatory, the three were the Professor of Astronomy, the Radcliffe Observer, and Professor Price. When any new measure was to be introduced for the furtherance of the interests of astronomy, or of science generally, Professor Price was nearly always the spokesman in congregation, just as he was generally expected to explain in congregation the bearings of any new measure dealing with financial concerns. In ways of this kind our late Fellow, though he contributed nothing to our astronomical knowledge directly, was yet a powerful ally. "He was regarded," says the writer above quoted, "both in Oxford and in London, as the best and surest friend of natural science. To no one are the museum and its departments more under obligation."

In 1857 Professor Price married Amy, daughter of Mr. William Cole, of Exmouth; this lady and several sons and daughters survive him. He was elected a Fellow of this Society 1856 June 13.

Herbert Sadler, son of the late Prebendary Sadler, was born in 1856. His grandfather was the M. T. Sadler, M.P., who first introduced factory legislation into Parliament in 1832. His mother was a daughter of Mr. Tidd-Pratt, the first Registrar-General of Friendly Societies. Herbert Sadler was educated at Sherborne (1870–73), and Queens' College Cambridge (1875–6). At the latter he held a small Exhibition for Hebrew. He did not take up any definite profession on leaving Cambridge, but did a good deal of miscellaneous scientific work. His knowledge of double-stars and double star catalogues was astonishingly complete, and he had almost a passion for collating and correcting

the literature in this field. The three papers which he communicated to the Society, of which he was elected a Fellow 1876 November 12, are all connected with this branch of Astronomy. The first was a criticism, in very unfortunate terms, of *Smyth's Celestial Cycle*; for the publication of this paper the Council afterwards formally expressed regret. The other two are lists of emendations and errata for the double-star catalogues in Vols. XL. and XXXV. of the *Mem. R.A.S.* All three papers show great industry; and the overhauling of the catalogues was supplemented by observations made by the author himself with a 3¼ inch Sheepshanks' instrument lent by this Society. In 1886 he published, in conjunction with Mr. Latimer Clark, a small work entitled "*The Star Guide*": *a list of the most remarkable Celestial objects visible with small telescopes.* His name frequently appeared in print as a contributor to *The Observatory*, *Knowledge*, and the *English Mechanic*. He was also much interested in the study of the lunar surface, and was associated with Mr. E. Nevill (Neison) in the formation of the "Selenographical Society"—a small association of lunar observers, which existed from 1879 to 1883 (when Mr. Neison left England for South Africa). Five volumes of the *Selenographical Journal* were published by this Society, and Mr. Sadler was a frequent contributor.

He never married. He died suddenly, 1898 June 1.

Alfred Fish Smith was born in London, 1832 December 25. He was a student at University College, London, under Professor De Morgan, and took his B.A. degree at London University in 1855. In 1851 he entered the Normal College of the British and Foreign School Society, Borough Road, London (now at Isleworth), as a student, and was, after a few months, appointed Acting Resident Officer for the College. In the following year he became Resident Officer, and subsequently Tutor, Mathematical Lecturer and Vice Principal, which last position he held for twenty years, resigning in 1888 from failing health. He married in 1860 Jane Sarah Wretts, of Ipswich, who died in 1885; his family consisted of six sons and six daughters, ten of whom survive him. He died in London, 1898 September 25.

He was elected a Fellow of this Society, 1869 January 8.

Josias Edward De Villiers, of Sea Point, South Africa, was a Fellow of our Society for little more than a year, having been elected 1897 January 8. He was killed in a railway accident 1898 August 16. Between Langsberg and Matjesfontein a goods train was being shunted at the top of the Mostertshoek gradient, and moving down the incline, crashed into the Johannesburg mail train. Mr. De Villiers, four other Europeans, and many natives were killed by the collision.

Mr. De Villiers joined the British Astronomical Association on the occasion of the total solar eclipse of 1896 August; and kindly reference is made in the Journal of the Association (1898 October) to the help he gave the expedition by his survey of the ground and his determination of the meridian line. This notice of him, which is practically here reproduced, reprints the following extract from the *Cape Argus* of 1898 August 17:

"Mr. De Villiers was a land surveyor by profession, and after many vicissitudes, which include some years' membership of the Free State Volksraad, he had acquired wealth and settled down to enjoy a life of cultivated leisure at Sea Point. His hobby was astronomy, and he had lately spent some thousands of pounds on a new observatory in his own grounds, which was about to be fitted with the finest of appliances. He had some taste in art, and was altogether one of the pleasantest of companions and most sociable of men. It was his delight to have his friends about him. He was returning from his canvass as Bond Candidate for Vryburg. A Progressive observed on hearing the sad news to-day: 'If all the Bondsmen were like him, I would not mind seeing fifty of them in the House.'"

George Williams was born at Baroche, in the Bombay Presidency, 1814 May 14. He was the eldest son of the late Colonel Monier Williams, Surveyor-General of that Presidency, and brother of Sir Monier Williams, K.C.I.E., the Boden Professor of Sanskrit in the University of Oxford.

At the age of seventeen he was articled to Mr. Decimus Burton, the well known architect of the entrance gates at Hyde Park Corner, of the Archway opposite, of the Athenæum Club, and other public buildings in the Metropolis. He served his full time of five years with Mr. Burton, and afterwards travelled for a year and a half in Italy and Greece. He devoted much of his time at Athens to drawings and measurements of the noble ruins on the Acropolis and its neighbourhood. Photography was not known in those days, and the student had to collect his materials by his own personal labour, his own careful drawings, his own exact measurements by tape and footrule. His industry was proved by the large number of drawings he brought home with him from Italy and Greece.

On his return to England he entered into partnership with his cousin, Mr. Arthur Williams, who was practising as an architect in Liverpool, and there he made the acquaintance of Mr. Lassell and Mr. Stanistreet, an acquaintance which ripened into a lifelong friendship. The rapidly increasing wealth and importance of Liverpool afforded ample scope for an architect of his acquired taste and education, and he was actively engaged for many years of his professional life in designing and constructing many of the public buildings and churches in that city, and of the residences of the prosperous mercantile men in the suburbs. The entire management of the Princes Park, which had just then

been generously given and dedicated to the public by Mr. Richard Yates, devolved on him.

Still, throughout all this press of business he found his recreation in the telescope and the microscope. He fitted up an astronomical telescope on the roof of his house in the Princes Park, and the small number of his friends who now survive will remember with pleasure the stated evenings at which they all assembled at his house to enjoy the discoveries of the microscope, the specimens on his slides being all prepared and mounted by himself with the greatest skill and nicety.

He found leisure in the summer of 1851 to accompany his friends Lassell and Stanistreet to Sweden to witness the total eclipse of the Sun visible in its totality on July 29, at, amongst other places, Trollhatten in that country. He wrote a full report of the result of his observations on that occasion.

Mr. George Williams' subsequent observations, though continuous, were not given to the public as he might have done had he desired to draw attention to himself. His diffident, retiring nature shrank from appearing in print or from any attempt to court publicity. On quitting his profession in the year 1880 (his wife having predeceased him), he took up his residence with his brother, Mr. C. R. Williams, at Dolmelynllyn, near Dolgelly, where an observatory was expressly erected for him containing a 5-inch telescope by Cooke of York, and where his investigations were sedulously carried out, chiefly connected with the spots in the Sun by day and the organism of the Moon by night. The results, as well as his observations on the transit of *Venus* on 1882 December 6, were from time to time accurately noted, but only occasionally communicated to the local press; and thus the scientific world has lost the benefit of his zeal and knowledge. He married Caroline, daughter of the Rev. Chas. Chauncy, rector of St. Paul's, Walden, Herts. She died in the year 1855. Mr. Williams died 1898 April 7. He was elected a Fellow of this Society, 1865 May 12.

[For the above particulars the Council is indebted to his brother, Mr. C. R. Williams.]

The Rev. Alfred Wrigley was born 1818 January 13, at Netherton, near Huddersfield, Yorkshire. When ten years old he went to Glasgow to commence his medical training, and for five years walked the hospital performing minor operations and obtaining the best possible certificates. At the age of fifteen he returned to England on the death of his father, and after a lapse of three or four years went to St. John's College, Cambridge, and graduated as seventeenth Wrangler in 1841 (Stokes's year). He was ordained and appointed to a position at Addiscombe College, and married in 1842 Maria Jane Worgan, grand-daughter of Dr. [illegible] well-known musician of the last century. He had one

son, who died in infancy; and two daughters, one of whom died in 1886. Mrs. Wrigley died in 1874.

On the breaking up of Addiscombe College in 1861 Dr. Wrigley came to Clapham as head-master of what was then the Clapham Grammar School, in succession to the late Rev. Charles Pritchard. This school he afterwards turned into a Training College for the Army and Civil Service, and as such it remained until 1882, when it was given up. Dr. Wrigley continued, however, to reside in Clapham until 1893, taking part in examinational work. For the last few years of his life he resided with Dr. Philpots, Moorcroft, Parkstone, Dorset. He died there 1898 January 30.

He was elected a Fellow 1842 March 11, and was thus our second oldest Fellow at the time of his death. He published no astronomical papers, and little can be now gathered as to his astronomical work, which was probably purely recreative. He was the author of a very successful collection of mathematical examples.

Cyrille Joseph Souillart was born at Bruay, in 1828, in a humble station of life. His aptitude for both science and letters was manifested very early, and he was a brilliant pupil at the Collège d'Arras, the Lycée de Douai and the Lycée Saint-Louis. He entered the École Normale, in 1851, and it was here, under the able tuition of M. Puiseux, that he became devoted to mathematical astronomy. On completing his course he was successively Professor at the Lycée de Saint-Omer; Professor of Mathématiques spéciales at Nancy, and also attached to the Faculty of Science; Professor of Mechanical Philosophy at Lille, and, some years later, of Astronomy.

For thirty years M. Souillart devoted himself to the Theory of Jupiter's Satellites. He began this work at first as the subject for a dissertation, and in the *Annales de l'École Normale* for 1865 appeared his *Essai sur la Théorie Analytique des Satellites de Jupiter*, which contains the nucleus of two great Memoirs subsequently published, the first in 1880, in the Memoirs of our Society, Vol. XLV., pp. 1 to 149; the second in 1889, in Vol. XXX. (II. Série), of the *Mémoires des Savants étrangers*, pp. 1 to 200. He also published some valuable notes on the subject in Vols. X., XI. and XII. of the *Bulletin Astronomique*. In the fourth volume of his *Mécanique Céleste*, M. Tisserand thus sums up the achievements of M. Souillart:—

"La théorie des satellites de Jupiter a pris, entre les mains de Laplace, une perfection qui n'a pas été surpassée. Toutefois les calculs n'avaient pas été poussés assez loin pour donner aux tables toute la précision compatible avec les observations. M. Souillart a eu le mérite d'y apporter les compléments nécessaires."

In the first Memoir above referred to M. Souillart develops the theory algebraically, and in the second he substitutes numerical values for the symbols. It remains for some one to

undertake the labour of forming tables from this perfected theory.

M. Souillart received the Lalande prize of the French Academy in 1882; the Damoiseau prize in 1886, the value being specially augmented to 10,000 francs; and a year before his death he was elected Correspondant de la Société d'Astronomie, in succession to Gyldén. He was appointed Chevalier de la Légion d'Honneur in 1891.

He was elected an Associate of our Society 1890, December 12.

Proceedings of Observatories.

The following reports of the proceedings of observatories during the past year have been received from the Directors of the several observatories, who are alone responsible for the same :—

Royal Observatory, Greenwich.

With the transit circle 10,626 observations of transits and 9,810 of zenith distances were made in 1898. The total number of stars observed is 5,000.

The Moon was observed 114 times with the transit circle; the mean error in R.A. of Hansen's *Lunar* Tables with Newcomb's corrections, as deduced from these observations, is $-0^{s}\cdot160$. The errors since 1883, when Newcomb's corrections were introduced into the *Nautical Almanac*, are as follows :—

	s		s		s
1883	+0·031	1889	+0·010	1894	−0·016
1884	+0·018	1890	+0·020	1895	−0·066
1885	+0·024	1891	+0·079	1896	−0·088
1886	+0·029	1892	+0·083	1897	−0·154
1887	+0·059	1893	+0·034	1898	−0·160
1888	+0·090				

The number of reflexion and direct observations of zenith distance of stars made during the year was 527. The apparent correction to the *Nadir* observation deduced from these is $-0''\cdot36$. The corrections from 1890 to 1898 are $+0''\cdot08$, $+0''\cdot07$, $-0''\cdot25$, $-0''\cdot34$, $-0''\cdot27$, $-0''\cdot31$, $-0''\cdot34$, $-0''\cdot27$, and $-0''\cdot36$.

Since the middle of 1895 July three observations of the *Nadir* have been made on a large number of days. Grouping the observations according to the time of day at which they were taken, the following changes of zenith point are shown :—

	9h–15h.	15h–21h.	21h–3h.
	″	″	″
1895	+0·29	0·00	+0·27
1896	+0·20	0·00	+0·16
1897	+0·11	0·00	+0·17
1898	+0·16	0·00	+0·11

The small value of the R—D discordance noted in the last report has been repeated in 1898. The observation of zenith distances of pairs of stars in which one star is observed directly and the other by reflexion alternately on alternate nights has been continued, and 82 pairs have been observed during the year.

A re-determination of the division errors of the transit circle was made in August and September. Two complete determinations of the errors of the 5° divisions were made. These results were combined with the determinations made in 1856 and 1871, the mean of the four giving a symmetrical determination in which each of the 5° divisions is obtained with equal accuracy. A new determination of the errors of the single degrees was also made and combined with the two previous determinations, the newly adopted values being used for the terminal 5° divisions. Further observations were made of the 5′ divisions used for the close circumpolar stars, and the results of previous determinations were collected and combined.

Two changes have been made in the printing of the meridian observations :—(1) From the beginning of 1897 the daily results are given only for the Sun, Moon, planets, and stars used for clock and instrumental errors. (2) In the annual catalogue of the 1897 observations the stars are brought up to 1900·0, the adopted epoch of the next catalogue ; and the form of the annual catalogues is now the same as for the general catalogues.

The progress of the ten-year catalogue for 1890 has been somewhat delayed by the re-determination of the division errors, and by the additional time required to bring up the 1897 observations to 1900·0. The mean right ascensions and North Polar distances of all the stars have been formed, and the positions obtained from observations above and below pole have been combined for the first twelve hours. It is anticipated that the copy for press will be made and ready for a final revision by the end of February. This final revision will necessarily take a considerable time, but it is hoped that the catalogue will be in print by the end of the year.

The new altazimuth has been severely tested during the past year by comparison of results in reversed positions of the instrument, and it has been found advisable to make some modifications in the counterpoises for the axis and in the attachments of the microscopes, and of the ends of the telescope tube. Astronomical observations were commenced in March, after a careful determination had been made of the division errors of both circles. After a little time it was found that the wheels carrying the microscopes had worked loose, and also that the axis was under constraint, the pivots not taking their positions freely in their bearings. The microscope wheels were more securely attached, and modifications were made in the counterpoise arrangements for the axis, roller bearings being tried in place of ball bearings. These, however, were, after many trials, not

found to work satisfactorily, and ultimately improved ball bearings in a hardened steel ring, with free suspension by a chain, were found to be quite successful. This modification was not completed till November 18, and it is now found that the direction of swing of the telescope has no effect on the readings of the microscopes.

Comet *b* (1898) *Perrine* has been observed on five nights, Comet *h* (1898) *Perrine-Chofardet* on one night, and Comet *i* (1898) *Brooks* on nine nights, with the Sheepshanks equatorial. Comet *Brooks* has also been observed with the 28-inch refractor, and was photographed on three nights with the 30-inch reflector of the Thompson equatorial.

Thirty-three occultations of stars by the Moon have been observed by one or more observers, as well as the occultation of *Venus* on May 22 and *Mars* on September 9. Nine phenomena of *Jupiter's* Satellites have been observed.

With the 28-inch refractor measures have been made of distance and position-angle of 310 double stars, each star being observed on the average on 2½ nights. Of those stars 76 were less than 0″·5 apart, 82 between 0″·5 and 1″·0, 70 between 1″·0 and 1″·5, and 82 over 2″·0. The following list gives some of the especially interesting pairs measured during the year :—

	Mags.		Dist.		Mags.		Dist.
Sirius	1	10	6″·0	Σ 1621	8½	10	2″·4
Procyon	1	10	6·0	Σ 1658	8	10	2·3
β 1071	3	14	5·0	β 800	7½	10	2·3
β 930	6	11	2·7	β 883	7·5	7·8	0·3
ζ *Herculis*	2	6	0·5	κ *Pegasi*	4·3	5·0	0·2

Of the 82 sets of measures of stars more than 2″·0 apart, a large number are of third stars near close pairs, and others are stars which are difficult on account of the difference of magnitude. A special series of measures of 70 Ophiuchi has been made on twelve nights extending from June 6 to September 15.

A balcony, giving an all-round view of the sky, has been erected round the building in which the 28-inch telescope is mounted, and is found to be very useful to the observers in doubtful weather.

Thompson Equatorial.—The re-working of the lenses of the 26-inch object glass for correction of coma in lateral pencils was completed by Sir H. Grubb in May, and the object glass was remounted. The slight figuring of the outer surface, which was shown to be required by photographs taken at Greenwich, was done on the spot, and, after being further tested by photographs taken inside and outside of focus, and with diaphragms, the object glass was finally approved in September.

A new 30-inch mirror of 11 ft. 3 in. focal length has been supplied by Dr. Common for the Cassegrain reflector, the focal

length of the original mirror being somewhat too long for the tube. The figure of the new mirror is very good, and it is quite satisfactory in every respect.

In the early part of the year some photographs of the Moon and stars were taken with the 30-in. Cassegrain reflector in the secondary focus. After the new mirror was mounted and adjusted, a number of photographs were taken in the principal focus, including a photograph of the nebula in Andromeda (exposure, 1 hour), which shows considerable detail, a series of photographs of planet *Eros*, and a number of photographs of *Neptune's* satellite.

With the 26-inch refractor some experimental photographs of close double stars have been obtained, which show that on a good night, with suitable exposure, stars $0''\cdot7$ apart can be just separated. *Neptune's* satellite has also been photographed with the refractor, and quite recently with the aid of an occulting shutter adapted to the plate-holder very successful photographs, admitting of accurate measurement of the position of the satellite, have been obtained, the image of *Neptune* (for which a short exposure was given) being very small and well defined, while the satellite (with a long exposure) is very distinct. A position micrometer (formerly used for the measurement of solar photographs) is being adapted by Mr. Simms to the measurement of small distances and position angles on photographs of this class.

Photographs were also taken of the large Sun spot group last September, the aperture of the 26-inch refractor being reduced to 15 inches, and a concave magnifier (telephoto combination) being used to enlarge the Sun's image to 29 inches diameter at the secondary focus. Enlargements from these negatives have been made on a scale of about 60 inches to the Sun's diameter.

With the *Astrographic Equatorial* 412 plates, with 722 exposures, have been taken on 113 nights. Of these 66 have been rejected, viz., 11 because the exposures were interrupted by cloud, 16 because the photographs did not come up to the standard in showing faint stars or were too dark for measurement, 18 owing to bad guiding or wrong setting, 18 owing to faults in development, imperfect printing of the reticule, &c., and 3 because the plates were bad. Of the 346 successful plates, 205 are for the chart, 131 for the catalogue, 8 for the adjustments of the instrument, 1 an attempt at planet *Eros*, and 1 of the Andromeda Nebula.

The following table shows the progress of the photo-mapping of the heavens to the end of 1898 :—

	Catalogue.	Chart.
Number of successful fields on 1897 Dec. 31	874	727
Number of successful fields taken in 1898	128	193
Number previously passed, rejected in 1898	31	0
Number of successful fields, 1898 Dec. 31	971	923
Number still required	178	226

Positives on glass of 359 chart-plates were made during the year, which, with the 539 reported last year, gives a total of 898.

During the year 1898 132 plates were measured, in the direct and reversed positions, and at the date of this report the measurement (in duplicate) of the stars in the Greenwich zones is completed from 64° to 70° N. decl.

The copy for press is completed for zones 64°, 65°, 66°, 67°, and that for 68° and 69° is in progress. The plate constants and the residuals of the reference stars, derived from the Zone Catalogues of the *Astronomische Gesellschaft*, are completed for plates whose centres are at declinations 65°, 66°, and 67°, and are in progress for those whose centres are at 68° and 69°.

The total numbers of stars measured in the different zones compared with the number in the B.D. and A.G.C. are approximately :—

Zones.	No. of Stars measured on Plates.	No. in B.D.	No. in A.G.C.
64°	9080	1900	1200 (Helsingfors)
65°	9237	2001	844 (Christiania)
66°	9494	1684	745 "
67°	9600	1285	574 "
68°	10200	1429	688 ...
69°	10650	1383	646 ...

Photographs of the Sun have been obtained on 173 days, either with the Dallmeyer photo-heliograph of 4 inches aperture, or with the Thompson photo-heliograph of 9 inches aperture (reduced to 6 inches); the former instrument being used regularly to 1898 July 27, and the latter from 1898 July 31. Of the photographs taken 374 have been selected for preservation, including 13 with a double image of the Sun, taken to determine the position of the wires with reference to the parallel of declination. Photographs have also been received from India up to 1898 November 16, and from Mauritius up to 1898 June 24, the year ending on the latter date being completely represented on every day by a photograph from one or other of the three observatories.

The Greenwich photographs have been measured in duplicate to the end of the year 1898, and the areas and heliographic positions of the spots and faculæ have been computed. The Indian and Mauritius photographs have also been measured and completely reduced so far as received. The copy for press of the daily results is complete to 1898 October 3 for the Greenwich and Indian photographs, but the numeration of the spot groups has been stopped at 1898 June 24, pending the arrival of further photographs from Mauritius. The copy for press is in the printers' hands up to 1898 June 10. The computations for the ledger are complete as far as 1898 February 28.

The mean daily spotted area of the Sun for 1897, expressed

as usual in millionths of the visible hemisphere, is 514 as compared with 1464, 1282, 974, and 543 for the years 1893, 1894, 1895, and 1896, respectively. A rough estimate for 1898 gives 380 for the mean daily spotted area for the year, showing a marked decline from the preceding year. This decline is chiefly due to the quiescence of the Sun during April and the three following months. The first three months of the year were fairly active, and there was a distinct revival of activity in August. But the most noteworthy incident of the year was the series of spot displays which commenced with the appearance of a great group on the east limb on 1898 September 3. The Sun was free from spots on about fifty days during the year, of which thirty-four fell during the minimum between 1898 March 18 and August 1.

As mentioned in the last report, the Astronomer Royal and Mr. Maunder went to India last year to observe the total eclipse of the Sun on 1898 January 22. The former took with him the Thompson 9-inch photographic telescope, with concave secondary magnifier, as arranged for the eclipse of 1896 in Japan, and with this obtained a series of six successful large-scale photographs of the corona, and also a series of photographs of the partial eclipse, for determination of the Moon's position relatively to the Sun, the local time and longitude of the station being determined by Major Burrard, R.E., and Lieutenant Crosthwaite, R.E., of the Indian Survey.

In order to strengthen the determination of the longitude of the western extremity of the great European arc, the longitude of Killorglin, at the head of Dingle Bay, Ireland, was determined in 1898 October and November. The station was selected in order to eliminate, as far as possible, the effect of local attraction at Valentia and Waterville, both of which longitude stations are situated between the Atlantic on the west and a mountain mass on the east. The observations at Killorglin and Greenwich were made by Mr. Dyson and Mr. Hollis, with transits D and E respectively, these instruments having been previously tested by observations in the front court of the Royal Observatory. The observations were in three groups of three, six, and three full nights respectively (or the equivalents in half nights), and the observers with their transit instruments were interchanged between the first and second groups, and again between the second and third.

The printing of the volume of *Greenwich Observations* for 1896 was completed in November. The transits, zenith distances, star ledgers, and the whole of the solar results have been printed for 1897.

The new Observatory building is practically finished. The four wings on the principal floor are occupied by the staff. The east, west, and north wings of the basement are to be fitted up as a library, the south wing being used as a workshop for the mechanics and carpenters. The upper floors will be used for the storage of manuscripts and records. The central portion of the

building, under the dome of the Thompson equatorial, is arranged as a museum and for the storage of instruments.

The new magnetic pavilion, situated in an enclosure in Greenwich Park, at a distance from the Observatory sufficient to secure the magnets from the possible influence of the large masses of iron in the instruments and buildings, was finished in the autumn, and is now used for absolute determinations of the magnetic elements. The standard meteorological instruments were transferred to this enclosure at the beginning of January.

Royal Observatory, Cape of Good Hope.

Mr. S. S. Hough, M.A., Fellow of St. John's College, Cambridge, has been appointed chief assistant *vice* Mr. W. H. Finlay, M.A., retired on account of bad health on August 28. Mr. Hough entered on residence at the Observatory on October 24. A skilled optical fitter, selected from the staff of Messrs. Troughton & Simms, has been added to the establishment of the Observatory.

The Lords Commissioners of the Admiralty have approved the proposals contained in the last report of H.M. Astronomer relative to the erection of a physical laboratory attached to the McClean Observatory, and of a new record-room providing a suitable accommodation for the measurement and preservation of astrographic photographs. The designs of both buildings have been approved and tenders called for, the work to be completed by the end of 1899 May.

The foundations have been built for the new transit circle. The Observatory itself, a construction of sheet steel, is weekly expected from Messrs. T. Cooke & Sons, York.

Messrs. Troughton & Simms report that the new transit circle will be ready in March next.

The equatorial mounting, and the object glasses of the McClean telescope, packed in forty-four cases, reached Table Bay on April 11. Within ten days all the cases had reached the Observatory, and the contents were found in perfect order. The work of erection was at once commenced with the aid of Cape workmen, under the constant supervision of H.M. Astronomer, and in six weeks all the parts were mounted and adjusted. The most troublesome part of the work, however, remained to be done, as Sir Howard Grubb had only erected the stand in the open air and no trials of the instrument in work had been made.

It is unnecessary here to enter into details of all the deficiencies of the stand as it was originally sent out. Mr. McClean most generously authorised the carrying out of all necessary alterations. The requisite iron castings and stays were designed, made, and fitted at the Cape, and now the stand is in every respect most steady, satisfactory, and convenient.

The electric lighting of the circles, micrometers, &c., with the

switches, rheostats, and fuses, had to be made or remodelled at the Cape.

The hydraulic motor for rotating the dome, with its reversing gear and valves, arrived on July 4, the hydraulic ram and valves for automatic clock-winding on October 11, and by November 1 the whole of the essentials of the Observatory and stand were fitted and in working order. Thus the raising or lowering of the floor and the rotation of the dome are commanded by cords, which can be operated by the observer at the eye-piece of the telescope with the utmost ease and delicacy, whilst the hydraulic gear, contrived by Mr. McClean, automatically winds the clock at short intervals, without communicating the slightest vibration to the telescope. All the hydraulic gear was made by the Glenfield Co., of Kilmarnock.

The 18-inch visual object glass has proved to be a very fine one, both the spherical and chromatic corrections being practically perfect as far as the flint and crown glass which are at present procurable in discs of that size will allow.

The 24-inch photographic object glass, unfortunately, has two faults—the marginal images show decided coma, and its minimum focus, instead of being for light of the refrangibility of H_γ (or, if anything, on the violet side of H_γ), is for rays about midway between H_β and H_γ. It is understood that Sir Howard Grubb will remedy these defects.

The slit spectroscope, for line-of-sight work, made by the Cambridge Instrument Co., was shipped from London on December 21. The 24-inch object glass cannot be conveniently returned to Sir Howard Grubb until tests have been made with this spectroscope as to the position of the slit in relation to the focal point of the object glass; because, from the construction of the spectroscope and the method of its attachment to the telescope, only a limited range of focal adjustment is possible.

Part 1, volume i. of the "Annals of the Cape Observatory" has been printed and circulated; it contains the observations of comets made in the years 1880–1894.

For reasons explained in last report, a new title page was issued to convert Part 2 of volume ii. into Part 5 of volume i.

Part 2, volume ii., "A catalogue of Southern double stars," is partly printed; the complete MS. has been sent to the printer.

Volume iv. of the Cape Annals (being Part 2 of the Cape Photographic Durchmusterung) was distributed during the past year.

Volume v., being Part 3 of the same work, is nearly completed. The MS. is in the hands of the printer as far as Decl. $-76°$, proofs have been received as far as Decl. $-69°$, and Professor Kapteyn reports that the remaining seventy or eighty pages required to complete the text will soon be ready. The question is now under consideration whether the detailed results of revision, including the observations of doubtful and determined variable stars, stars of considerable proper motion, &c., should be

published in their present state, or whether these observations when completed should be published in a separate volume.

Volumes vi. and vii., being "A Determination of the Solar Parallax and Mass of the Moon from Observations of *Iris*, *Victoria*, and *Sappho*," were distributed to astronomers partly in 1897, partly in 1898.

Volume viii., Part 1, "Investigations on the Parallax of the Principal Fixed Stars of the Southern Hemisphere," is nearly completed in MS., but has not yet been sent to the printer.

The Cape general Catalogue of 3007 stars for 1890, with appendices, has been printed. One appendix contains a comparison of the Cape 1890 Catalogue with other Catalogues of Southern stars; and the other appendix contains a discussion of the places and proper motions of twenty-four southern circumpolar stars.

The day numbers for the years 1899 and 1900, corresponding to Finlay's star-reduction tables, have been printed and distributed. Those for 1901 have been forwarded for printing.

The annual results of the meridian observations 1860–65, made under the direction of Sir Thomas Maclear and recently reduced, have been printed and distributed; those of 1866–70 are in the hands of the printer.

Considerable progress has been made in the preparation of a general catalogue of stars for the equinox 1865 from these observations.

A list of 2798 zodiacal stars for the equinox 1900 has been prepared in accordance with Resolution 9 of the International Conference on Fundamental Stars held at Paris in the year 1896. The first proofs of the work have been returned to the printer for correction.

The work of the present transit circle has been confined to observations of standard stars required for the reduction of the international "Catalogue Plates." The whole of the standard stars for the zone $-44°$ to $-47°$ (both inclusive), with a minimum of three observations for each star, have been observed during the year.

The working list for the final zone $-48°$ to $-51°$ (both inclusive) has been prepared, and it is expected that the observations will be completed by the end of 1899. The whole will constitute a catalogue of about 9000 stars between the Declinations $-40° 0'$ and $-52° 0'$, giving the places of from ten to twelve well-distributed standard stars for each of the plates of the Cape astrographic zone.

The observations made with the transit circle during the year have been:—

Meridian Transits	10355
Determinations of Z. D.	9863
" Collimation	101
" Level	349

Determinations of Azimuth	... ...	293
" Runs	... ...	345
" Nadir	... ...	329
" Flexure	... ...	21
Obs. of Meridian Mark, in Azimuth	... ...	175
" Z. D.	... ...	45

The reductions of the meridian observations to mean place both in R.A. and N.P.D., and the formation of the ledgers, is complete to 1898 December 31.

Observations of 148 separate phenomena of occultations were obtained as follows, of which twelve were made during the total eclipse of the Moon on December 27 :—

	D.B.	D.D.	R.B.	R.D.	Total.
Predicted by the N.A. Office ...	0	28	0	21	49
Miscellaneous Stars	0	73	0	14	87
Total Eclipse		11	...	1	12
				Total	148

Of these 148 phenomena, two were observed by four observers, eight were observed by three observers, twenty-four were observed by two observers, and 114 were observed by one observer.

Coddington's Comet was observed on fourteen nights, between August 21 and October 28, with the 7-inch or McClean equatorials, on seven nights with the heliometer, and on eight nights, between June 21 and July 18, with the transit circle.

Giacobini's Comet was observed on three nights with the heliometer.

Mr. Innes has been chiefly occupied with the 7-inch equatorial in the revision of eight lists of stars which have been communicated by Professor Kapteyn since the date of the last report—viz. :

List V. 25 stars contained in catalogues of precision missing in the C.P.D.

List VI. 43 stars contained in catalogues of precision missing in the C.P.D.

List VII. 35 stars contained in catalogues of precision missing in the C.P.D.

List VIII. 23 stars brighter than 9·1 contained in Thome missing in the C.P.D. −34° to −38° Dec.

List IX. 23 stars brighter than 9·1 contained in Thome missing in the C.P.D. −38° to −42° Dec.

List X. 48 stars 9·2 or brighter found only in the C.P.D.

List XI. 315 stars in catalogues of precision missing in C.P.D. $-67\frac{1}{2}°$ to −72°.

List XII. 94 stars in catalogues of precision missing in C.P.D. −72° to −77°.

Every star in Lists V. to IX. has been looked for with the following results :—

33 are coloured stars ; in 49 cases there is no star in the assigned place ; all the rest are 9·5 mag. or fainter.

All the stars of List X. have been verified (*i.e.* of visual mag. 8·75 to 9·3), except Nos. 11 to 47, all of which are contained in the star cluster Messier 7, the components of which Thome did not attempt to register completely.

Lists XI. and XII. are in course of observation.

Many of the stars in the above lists are still being observed under suspicion of variability. No error has been found in the C.P.D.

During the year Mr. Innes has also discovered 53 new double stars with the 7-inch equatorial, and Messrs. Pett and Cox three with the transit circle.

The regular observation of all oppositions of major planets with the heliometer, mentioned in last report, has been undertaken, and will be systematically continued.

	No. of Sets.	No. of Measures.
Opposition of Jupiter	8	53
„ „ Saturn	$5\frac{1}{2}$	44
„ „ Uranus	7	45
„ „ Neptune................	9	72

A *measure* means a complete observation of instrumental distance or position angle—*i.e.* four pointings in all, viz. one in each of two positions of the reversing prism in each of two reversed positions of the object-glass segments, or eight pointings if the limbs are observed instead of the centre of the planet.

A *set* means a complete symmetrical determination of the position of the planet with respect to symmetrically situated comparison stars—viz. position-angle and distance from each of two opposite stars, or measures of distance only from three or four symmetrically surrounding stars. In every set the measures are symmetrically arranged in the order α, β, γ, γ, β, α, &c., so that the mean epoch of observation for each comparison star is approximately the same.

In Triangulation I., connecting 36 comparison stars available for *Uranus* in 1898, 1899, and 1900, for *Saturn* in 1898, and *Jupiter* in 1900, there have been measured in 1898 :

Distances.	Position Angles.
In the Triangulation, 38 ; Standards, 16.	In the Triangulation, 7 , Standards, 4,

in addition to 103 distances and 63 position angles measured in 1897.

In Triangulation II., connecting together 19 stars required for heliometer observations of *Neptune* in 1897, 1898, 1899, and 1900, have been observed :

Distances.	Position Angles.
In the Triangulation, 83 ; Standards, 30.	In the Triangulation, 7 ; Standards, 4.

The results of an excellent series of meridian observations of

50 of these comparison stars have been received from Professor Tucker, of the Lick Observatory.

A printed list of the comparison stars to be employed in these observations till 1900 inclusive has been distributed, with requests for the co-operation of meridian observatories.

The heliometer has also been employed in continuing the triangulation of 21 stars in the neighbourhood of the South Pole, as mentioned in last report. 219 distances in this triangulation and 103 observations of the standard distance have been made during the year.

16 sets of evening and 15 sets of morning observations of red stars, symmetrically situated relative to white stars of nearly the same declination, have been observed in the winter months. The correction depending on atmospheric chromatic dispersion, whose coefficient is tan ζ cos $(p-q)$, comes out smaller than its small probable error. The observations will be continued next winter.

30 sets of observations connected with determination of the parallax of various stars, and 70 observations of the distance and position angle of the components of *α Centauri*, have been made.

The systematic reduction of the series of 550 observations of the mutual distances and position angles of *Jupiter's* satellites, made by Gill and Finlay in the year 1891, and the comparison of the observed with the tabular quantities, has been undertaken and is now well advanced.

The final discussion of the zenith telescope observations for determining the constant of aberration and variation of latitude is not yet complete.

The final discussion of the observations of 436 pairs of stars, made with the zenith telescope in 1886–91, is deferred until the results of the late Dr. Romberg's observations of the northern components of these pairs made with the Pulkowa transit circle have been published.

Mr. de Sitter has been engaged with a Zöllner photometer, applied to the 6-inch Grubb equatorial, in comparing the relation betwen visual and photographic magnitudes of stars in regions near the pole and the equator of the Milky Way, and has made 349 observations on 27 nights.

With the astrographic telescope the following work has been accomplished:

	No. of Plates.	No. of Exposures.	Duration of Exposure.
Triple Chart Plates	199	597	30^m
Incomplete Chart Plates	40	...	...
Revision Catalogue Plates	200	600	6^m, 3^m, 20^s
Special Plates for Variables, &c....	16	48	Various
Coddington's Comet, long exposure	2	2	120^m
„ „ short „	3	3	5^m
Trails and Plates for Centreing ...	9	...	...
	469		

With reference to the "revision catalogue plates," it is proposed to repeat the whole series, in order to bring the epoch at which the plates were taken nearer to that at which the comparison stars were observed on the meridian.

The labour of taking the plates is so trifling compared with that of measurement and reduction, that the proposed course seems to be advisable; besides, this plan permits suspected cases of large proper motion to be readily and satisfactorily dealt with.

A description of the new instrument made by Messrs. Repsold for measuring catalogue plates has been communicated to the Society.

The instrument was received in the end of 1897. Some small alterations had to be made upon it, and for various reasons it was not until August that a beginning could be made, on a small scale, in measuring the plates. Thus only 27 catalogue plates, containing 9,066 stars, have been measured. All these have been measured in two positions reversed 180° from each other; an example of the character of the work obtained is given in connection with the description of the measuring instrument. A second measuring instrument has been ordered from Messrs. Repsold, and when this and the new convenient measuring room are ready it will be possible to organise a more efficient measuring staff, and to push on the work at a more rapid rate.

Attempts were made to photograph the paths of the *Leonid* meteors on November 13 and 14, but without success. An account of the attempt and of the visual observations has been communicated to the Society.

The field operations of the Geodetic Survey of Rhodesia were resumed in May, after the rainy season.

During the early part of the year the observers were trained at the Observatory in the use of the Jäderin base measuring apparatus, and the constants of the measuring wires were determined by comparison at various temperatures with the Cape measuring bars, whose constants are known with very great precision. (Geodetic Survey of South Africa, pp. [11] to [55].)

The difference of longitude between Bulawayo and the Cape Observatory was determined by exchange of telegraph signals on four nights, with time determinations at both ends. Astronomical latitude and azimuth were also determined during the same period—May 16 to 23. A site for a base line was then selected, and a base of $11\frac{3}{4}$ miles in length was measured forward and backward with the Jäderin apparatus. Seventeen stations have since been occupied with the Repsold theodolite, and the horizontal and vertical angles of surrounding stations measured; astronomical latitude has been determined at seven of these stations, and azimuth at four of them. Mr. A. Simms is in charge of the field work. In the end of August the Jäderin apparatus was returned to the Observatory, when numerous comparisons with the Cape standards were again made, and many experi-

ments were carried out with a view to increase the efficiency of this convenient apparatus in the measurement of geodetic base lines. An account of these experiments will be subsequently published.

An arrangement for delimitation of the Anglo-German boundary between British Bechuanaland and German South-West Africa, which was submitted in 1896 by H.M. Astronomer and Baron von Danckelmann (the geographical expert attached to the German Foreign Office), was finally approved on 1898 January 1 by both governments concerned.

In February Lieutenant Wettstein came to the Observatory, where he worked for some months in preparation for his duties as German Commissioner on the Survey. He left for Damaraland in August to organise the transport for the survey party. Major Laffan, R.E., the British Commissioner, who had previous experience on the Geodetic Survey of South Africa, reached the Cape a few days before Lieutenant Wettstein's departure, and spent two months at the Observatory in practising astronomical observations and in general preparation. Major Laffan reached Reitfontein (Long. 20° E. Lat. 26° 47′ S.) on November 19. Field work was commenced by determinations of Astronomical latitude on four nights and azimuth on three nights. A reconnaissance is now in progress for selection and beaconing of points.

These operations, both in Rhodesia and in the Anglo-German boundary, are under the direction of H.M. Astronomer.

Mr. Rhodes has promised that so soon as he is in a position to commence the extension of the railway from Bulawayo to the Zambesi, he will place at the disposal of H.M. Astronomer the funds necessary to carry on the arc of meridian from Southern Rhodesia to Lake Tanganyika. Thus in course of a few years the following geodetic data will probably be available :—

1. An arc of meridian, along the 20th meridian of East Longitude from Cape Agulhas (Lat. 34° 49′ S.) to Lat. 22° S. perhaps to Lat. 18° S.
2. An arc along the meridian of 30° E. Longitude from the South of Rhodesia (Lat. 22° S.) to the Southern extremity of Lake Tanganyika (Lat. 8° 40′ S.).

It is hoped that the German Government will carry on this arc along the eastern border of Lake Tanganyika to Uganda. The way is also now clear for an arc of meridian from Alexandria along the Nile to Uganda—*i.e.* practically along the same meridian of 30° E. Longitude. This latter work is not alone important for scientific reasons; it is also necessary for the practical cartography of the country, and it is to be hoped that it will be undertaken ere long.

Telegraphic signals, with time determinations at both ends, were exchanged with the Observatory on three nights by Captain

Close, R.E., and Dr. E. Kohlschutter (members of the Commission for Delimitation of the Anglo-German Boundary from Lake Nyassa to Lake Tanganyika), in order to determine the longitude of Nkata Bay on Lake Nyassa. The previously accepted longitude was found to be six miles in error.

Similar signals were also exchanged on two nights with Captain Watherston, R.E. (a member of the Anglo-Portuguese Barué Delimitation Commission), to determine the longitude of Umtali. The operations in both cases were completely successful.

On the recommendation of a Committee of the British Association the purchase of a self-recording Milne-seismograph was sanctioned. The instrument, made by Mr. R. W. Munro, of London, has reached the Observatory, and will soon be mounted.

The meteorological observations made during 1898 have been communicated to the Cape Meteorological Commission.

Royal Observatory, Edinburgh.

The routine work of the Observatory has been carried on as in the preceding year, the same instruments being in use, and the various departments of work under the charge of the same members of the staff.

The time service has on the whole worked very satisfactorily, though unfortunately accidentally interrupted several times by the workmen employed on the extensive architectural alterations at present proceeding on some of the buildings to which the controlling wires were attached. To this cause must be referred the necessity for stopping the one o'clock signals on March 30, on five days in November, and on December 1 and 2.

The meteorological observations have also been made under the same conditions as in last year, and the monthly copies of the daily readings continue to be supplied to the Scottish Meteorological Society, for the use of the Registrar-General for Scotland. The tabulation and discussion of the hourly values of the Anemometer Curves have been undertaken by Mr. Ramsay.

The observations with the Meridian Circle were made by Dr. Halm throughout the year. Besides the stars used for the control of the clocks, a series of circumpolar stars was observed during the first three months, for the purpose of investigating the latitude and refractional peculiarities. Since April the instrument has been used for the determination of the places of the *Nautical Almanac* Zodiacal stars. Of these a considerable number of observations has been secured and reduced. At the close of the year the programme was further extended by including a list of stars selected for use in the Cape Heliometer observations at the oppositions of the chief major planets.

The new reduction of the right ascensions of the old Edinburgh Catalogue has been further advanced by Dr. Halm, assisted by Mr. Neustadt, who has been temporarily engaged as

computer. The calculations were much facilitated by means of a machine invented by Dr. Halm, which gives the sum of the instrumental corrections by a single setting, and has proved a remarkable economiser of time and labour. The years 1834–36 and 1841–45 are now completed, and a preliminary comparison has been made with the *Fundamental-Catalog*, which shows that the new reductions are in full accordance with this standard. For the remaining years the investigation of the instrumental errors has been carried out. The reduction of the declinations has been commenced by Mr. Heath, who has revised the refractions for 1834–37. The refractions for the years 1834–39 were originally computed by Ivory's Tables, and the corrections necessary to reduce them to Bessel are given by a table arranged by Mr. Heath. At first it was considered advisable to compute the refractions anew for all zenith distances greater than 70°; experience has shown, however, that it is quite safe to use the table down to 75°, and this course will be adopted for the two years still to be revised.

The bifilar pendulum and photographic recording apparatus presented to the Observatory by the late M. Antoine d'Abbadie has been kept in operation during the year. A second pendulum, purchased out of a grant made to the Observatory by the Research Committee of the Royal Society, was placed in position in May. Its site is in the same basement cellar as the old pendulum, and it is so placed as to be sensitive to tilts in the East and West direction, or at right angles to the direction of vibration of the older pendulum. Earth tremors in any direction and of sufficient intensity are thus shown by one or both of the instruments. By a suitable arrangement of reflecting mirrors both the pendulums record their movements on the same roll of photographic paper. Very small oscillations were recorded on January 24 and 29, February 18, and April 22, by the North-South pendulum. With these exceptions, there is little of interest in the records of the year, the traces being for the most part straight and undisturbed lines. The curves, while uninteresting from a seismological point of view, are, however, very reassuring as to the stability of the Astronomical instruments.

The total Solar Eclipse of January 22, 1898, was observed at Ghoglee, in the Central Provinces of India, by Professor Copeland and Engineer McPherson. A preliminary report giving details of the instruments used and the methods of observation adopted, together with some indication of the results, was published in the *Proceedings* of the Royal Society, and reprinted in the Appendix to Vol. LVIII. of the *Monthly Notices* of the Royal Astronomical Society. A final report is in preparation, and a series of photographs of the ultra-violet spectra of sunlight and of some metals has been made, with the Iceland spar prismatic camera, by Mr. Heath and Mr. Ramsay, for comparison with the Indian photographs.

Watch was kept for the *Leonid* meteors on November 13, 14, and 15, and for the *Bielids* on November 24, with the results published in the *Monthly Notices* for December 1898.

Preparations were made for observing the occultations of small stars during the total Lunar Eclipse of December 27, but it was found impossible to use any of the larger instruments owing to a violent storm of wind and rain from the S.W. The average velocity of the wind, as shown by the anemometer curves for the day, was over 67 miles per hour. The violence of the wind culminated at 5 P.M. and again at 9 P.M., when the hourly velocity reached 74 miles, and for a short period, about 5 o'clock, as much as 80 miles per hour appears to have been registered.

The final arrangement of the books in the Crawford Library has been completed by Mr. Ramsay, who has devoted a large amount of time and attention to this important work during the year.

No. 53 of the *Edinburgh Circulars*, calling the attention of observers to the possible re-appearance of the *Biela* meteors, was issued on November 21.

Armagh Observatory.

With the refractor observations of double-stars and occasional phenomena have been made, but the weather was on the whole very unfavourable. Neither the *Leonids* nor the total eclipse of the Moon could be seen owing to clouds.

At the request of Professor Auwers, the reductions of a number of star-places in the first *Armagh Catalogue* were examined, and some errors were found. It became evident during this examination that the positions given in that Catalogue could be very materially improved by a complete new reduction of the original observations, and if ever the necessary pecuniary means should be found, it would be well worth undertaking this work, considering the paucity of observations of Bradley's stars during the first half of the present century.

The astronomer has received a grant from the Government Grant Committee for procuring a micrometer microscope for measuring a number of photographic plates of nebulæ, which Dr. Isaac Roberts has kindly promised to lend for this purpose. This instrument has just been received from Messrs. Troughton & Simms.

Cambridge Observatory.

The chief event of the year has been the erection of the new photographic equatorial, which will be known as the Sheepshanks Telescope. A preliminary account of this instrument appears in the *Monthly Notices* (1899 January, *ante* p. 152).

The building to contain it was ready by the end of June, and the instrument arrived from Sir Howard Grubb's works at the end of July. The heavy parts were erected in the first days of August; the building was then completed, and by the middle of September the erection of the instrument was in the main finished.

The work of adjustment is necessarily complicated by the introduction of the plane mirror, the non-reversibility of the instrument, and the impossibility of observing within 20° of the pole. Several additional instrumental errors are introduced which are not easily separated from the others; and many of the ordinary methods of adjustment are not applicable to the new form. It has therefore been necessary to devise new methods, and the work, which would in any case have necessarily proceeded slowly, has been much hindered by bad weather. A number of photographs have been taken for adjustments, &c., but it is not yet possible to speak of the performance of the instrument. All that can at present be said is, that things promise well.

A machine for measuring the photographs has been designed, and is now being constructed by the Cambridge Scientific Instrument Company. It is essentially a form of the instrument designed by Professor Turner for the work of the Astrographic Chart, modified to give the greater accuracy required in stellar parallax work. The position of a star with reference to the adjacent *réseau* lines is measured on a glass scale in the eyepiece, which is moved in each coordinate by micrometer screws. The measurements are thus made in terms of the whole divisions of the scale, which are read directly from the scale, and in parts of a division, which are measured by the screws, not estimated. The use of the micrometer screws is thus reduced to a minimum, which will, it is hoped, increase the rapidity of measurement and diminish the wear of the screw.

In the course of the year the Meridian Circle has been used chiefly for the purpose of re-observing those stars of which the places in the Catalogue of the *Astronomische Gesellschaft* $+25° \ldots +30°$ depend on a single observation. 101 nights were available, and on these 3055 complete observations have been taken; among these, 651 standard stars, for clock correction, and 163 stars near the Pole for instrumental error, *Polaris* being the one almost generally used for this purpose. It was observed 68 times above the Pole and 88 times below. The result is that out of 1420 star places which required examination about 50 remain to be re-observed.

During the month of April advantage was taken of some gaps in the working list to observe Harrow Occultation Stars, at the request of Colonel Tupman.

For convenience of calculation, the transit wires have been carefully adjusted, at moderate intervals of time, so as to leave the observations practically free from error of collimation, or rather from collimation and diurnal aberration combined. This

has considerably facilitated the work of reduction, which has nearly kept pace with the observations.

The nadir point and level have been carefully and regularly observed; and the constants for instrumental correction obtained by the solution of 131 equations.

The right ascension wires have remained whole for a good many years; yet a fresh determination of the intervals is made at the end of each year, from all the suitable observations of *Polaris* made during the previous twelve months. The intervals have already been calculated from 115 observations made in the past year. One was rejected because the R.A. micrometer screw had been tampered with during the observation, several because the image had been very bad, or so faint as to make the observation unreliable, and more because the centre wire had not been observed.

Vol. XXIII. of the Cambridge Astronomical Observations has been issued from the University Press. It comprises the work done for the Zone Catalogue during the years 1872 ... 1875. The printing of the larger catalogue has been deferred until the final determinations of some of the star places can be incorporated.

The occultation of *Venus*, 1898 May 22, was observed with the Northumberland Equatorial, and the results have been communicated to the Society. Observations of the total lunar eclipse, 1898 December 27, were prevented by bad weather.

A five-inch portrait lens is mounted on the Northumberland Equatorial, and preparations were made to photograph trails of the *Lyrids*, *Leonids*, and *Andromedids*; but bad weather made it impossible to obtain any results. Some visual observations of *Leonids*, made through clouds on 1898 November 14, have been communicated to the Society.

An increasing number of members of the University has attended the classes in practical astronomy.

The Newall Telescope, Cambridge Observatory.

The Newall telescope was used for observation on eighty-five nights in the course of the year 1898. Twice in the year there have been unusually long spells of consecutive nights on which clouds rendered it useless to attempt observation—viz. in January, twenty-seven nights, and in November and December, thirty-three nights.

The instrument has been employed throughout the year, in connexion with the Bruce spectroscope, in taking photographs of stellar spectra for the determination of velocity in the line of sight. The observations have been mainly restricted to stars that have spectra more or less similar to that of the Sun. In the course of the year 141 photographs have been obtained, giving material for the determination of velocity for 59 stars. Twenty-three

of these stars are included in the list of 51 stars, for which the velocity in the line of sight was determined at Potsdam in the years 1888 to 1891. The remaining 36 stars are fainter than could be successfully dealt with at Potsdam, the magnitude lying between 2·5 and 4·0. The duration of exposure for each photograph has usually been about 60 minutes. A considerable number of plates have been rejected, because the exposures were interrupted by cloud.

Of the photographs secured during the year, 95 have been measured and reduced in the method referred to in previous reports. Much time has, however, been devoted to developing another method of measurement and reduction, the aim being to make use of lines in the stellar spectrum which do not occur in the comparison spectrum of the iron spark, and so to employ a much larger number of lines than has hitherto been used, and also to deduce velocities for stars other than those of solar type. Some idea of the results of the method may be gathered from a special instance, though the numbers given must still be regarded as provisional. The velocity of *a Cygni* was determined by the old method, by direct comparison of five stellar lines with lines in the iron spectrum, and was found to be −10·9 kilometres per second. By the new method, now referred to, the velocity has been deduced from the same photograph (C. 446) by making use of 48 lines in the star spectrum, and is found to be −12·6 kilometres per second. The velocity deduced from another photograph of the same star, 62 lines being used, is −13·4 kilometres per second, and an analysis of the determinations for different lines gives the following results :—

		Velocity km./sec.
From 17	Iron lines	−16·8 ± 1·7
7	"Enhanced" iron lines	− 6·4 ± 2·8
20	Titanium	−13·1 ± 2·0
3	Scandium (?)	−15·7 ± 5·2
1	Hydrogen	−11·8 ...
2	Magnesium	−14·3 ...
6	Chromium	−10·4 ± 2·6
6	Unknown origin	−12·8 ± 2·6
62	Mean ...	−13·4

It will be realised that in this method it is hoped that material may be found for a search for signs of pressure in stellar atmospheres. According to Messrs. Humphreys and Mohler's experiments, it would be expected that those substances which give the smallest velocities in the above list are those subject to the highest pressure.

Dunsink Observatory.

During the past year 1602 observations were made with the meridian circle. These include 73 determinations of the collimation error, 73 of level, 60 of azimuth, 20 of runs, and 48 of the nadir point by reflection. 189 observations of standard stars were made in right ascension, and 157 in declination. A list of 206 stars of reference for reducing photographs of 50 selected clusters having been drawn up, the meridian observation of these stars was commenced on 1898 May 6. The observations of these stars number 488 in right ascension and 494 in declination. Those in right ascension have been reduced to apparent place to date, those in declination to December 12, and all to mean place to December 2.

With the "Roberts" equatorial forty-eight photographs of star clusters and nebulæ have been taken, besides a number of photographs of the eclipses of the Moon and of objects not intended for measurement. Two photographs of the Moon of ten minutes' exposure, taken on rapid plates during the totality of the recent eclipse, show a good deal of detail all over the image.

The "South" equatorial was also used during the eclipse in determining the times of occultations of faint stars.

The time-service to Dublin has been continued as usual, and the Observatory has been open to the public on the first Saturday of every month, and to students of Trinity College weekly during Michaelmas term.

Glasgow Observatory.

The weather during the past year was not favourable for astronomical observations. There were 119 nights in the year on which stars could be seen at some time or other, but on only forty-seven nights did a clear, but not always cloudless, sky last for three hours and upwards.

The Transit Circle was used on thirty-seven nights on observations of α and λ *Ursæ Minoris*, and of *B.D.* 89°, 37. The rectangular co-ordinates of the last mentioned star were measured in a bright field by means of the screws of the micrometer at least twice during a night, the interval between the first and last observations being as great as the weather permitted; the maximum interval was thirteen hours. Immediately before or after each observation the collimation, inclination, and nadir point were determined, and the position of the azimuth mark noted. The inclination of the horizontal wire was successfully determined by means of a theodolite, which was mounted in close proximity to the object-glass; this determination agreed closely with that obtained from numerous observations of equatorial stars. The Transit Circle was ten times reversed in its bearings.

The 20-inch reflector with spectrograph was employed on thirteen nights during the summer months in experimental work. As the flexure of the mounting proved too considerable for long exposures, the mounting was strengthened so as to prevent the prism from tilting. In consequence of this alteration, the amplitude of the flexure became independent of the declination and was reduced to $1\frac{1}{2}'$, or about one-fifth of its former value. When the instrument is turned in hour-angle through twenty-four hours, the image of each individual point of the slit oscillates in a straight line on the plate almost parallel to the slit. Owing to its regular behaviour the flexure can be conveniently allowed for in the manner explained in last year's report. At the end of the year a photograph of a $5\frac{1}{2}$ magnitude star was obtained with an exposure of six hours and slit 0·018 mm. wide; on this plate the star spectrum is linear, and the definition of the stellar and comparison lines is as good as in the short exposures of bright stars. During the last quarter of the year the instrument could only be used twice as the atmosphere on the few clear nights was so moist that the mirror could not with safety be uncovered.

A continuous look-out was kept for the *Leonids* until daybreak on November 13 to 15. On November 13 at 15^h G.M.T. one *Leonid* was noted through drifting clouds. On November 14 it was overcast until 15^h G.M.T.; from $15^h\ 3^m$ to $16^h\ 14^m$ the sky was partially clear and seventeen *Leonids* were recorded.

On November 23, when a watch till daybreak was kept for the *Biela* meteors, the sky was overcast during the whole night.

The observation of the star occultations during the lunar eclipse on December 27 was frustrated by rain.

The time service and the extensive meteorological work have been carried on as in former years.

Liverpool Observatory.

The instrumental equipment of the Liverpool Observatory, and the nature of the work carried on, are practically the same as at the date of the last Report. The illumination of the field and of the circles of the equatorial, effected by means of electric lamps, having become disarranged, the system was examined and renewed by Sir H. Grubb in the course of the year, with the result that the effectiveness of the instrument has been much increased. The seismological observations have been continued throughout the year, and it is hoped to still further extend the series, so as to trace, if possible, the existence of the passage of earth-waves of long period and small amplitude due to tidal effects in the estuaries of the Dee and Mersey.

The examination of various kinds of instruments and the issue of certificates under the regulations sanctioned by the Mersey Docks and Harbour Board, have been continued, and the

number of such instruments submitted for examination is slightly on the increase. The distribution of time-signals is continued as heretofore. Some improvements have been introduced into the method of firing the one o'clock time-gun, which it is hoped will ensure increased accuracy and regularity in the signal. Meteorological observations are regularly pursued as in former years, and the results are forwarded to various public departments. Assistance is given to local sanitary authorities in an attempt to connect prevalent zymotic diseases with atmospheric conditions.

Recent storms caused some damage to the exposed Robinson and Osler's anemometers, but the observations were interrupted for a very short time.

The equatorial is used for the observation of occultations, measurements of the diameter of planets, and for the determination of cometary places. These last have been communicated to the Royal Astronomical Society. With the transit instrument, the observations of those circumpolar stars, suggested by Professor Auwers in *Ast. Nach.*, No. 3440, have been continued, and the results will shortly be published by order of the Mersey Docks and Harbour Board.

Radcliffe Observatory, Oxford.

The observations with the Transit Circle have been carried on pretty regularly throughout the year. During the summer a short interruption occurred through the necessity of making some alterations in the floor of the Transit Circle room, and in the autumn observations were discontinued for a short while to enable the computing staff to overtake some reductions.

The following objects have been included in the observing-list for this instrument. The Sun, and the Moon (during the first half of the lunation); zodiacal stars; stars to the 7th magnitude lying between 85° and 90° N.P.D.; comet comparison stars; variables; and certain other selected objects.

During the year the number of transits observed amounted to 2,252, and of zenith-distances to 1,948. These include 86 observations of the Sun in R.A. and 82 in N.P.D.; 31 of the Moon in R.A. and 26 in N.P.D.; and 47 observations of stars, direct and reflected.

The Barclay Equatorial has been used in the following miscellaneous observations :—

1. Estimates of magnitude :

(*a*) *Albany* 7906 (a white star), on September 15, 16, October 24, and December 19. The magnitudes as given by Argelander and in *Albany* are, respectively, 6·5 and 6·3. The Oxford estimations made with the Barclay and Transit Circle lead to a value 7·4.

(*b*) *Arg. Z.* + 51°, 244. The distance of the components was also measured with the ring-micrometer.

(*c*) *Arg. Z.* + 16°, 1194, 1196, 1200, and 1201. For 1194 and 1200 Argelander gives the magnitudes 8·5 and 9·0, while the Oxford estimations lead to the values 9·2 and 8·8 respectively.

(*d*) Ceraski's New Variable compared with 20 stars in same field on September 2, 3, and 20.

(*e*) *Nova Aurigæ*. This star had again diminished in brightness. The estimates in 1898 were, on January 19, March 2, and March 14, 12·0, 12·4, and 12·2 respectively. The mean of similar observations in 1897 was 11·5.

2. Observations of the colour of the following stars:—*B.A.C.* 4287, ε *Aquarii*, *Arg. Z.* + 16°, 1194, and of the comparison stars observed with *Albany* 7906.

3. Witt's Planet (433), *Eros*. Observed on September 5 and 6.

4. Occultations by the Moon:

(*a*) The occultation of the *Pleiades* was observed on January 3, and the results have been communicated to the Society.

(*b*) Preparations were made for observing the occultation of *Venus* on May 22, and

(*c*) for observing occultations of stars during the total lunar eclipse of December 27.

On both occasions clouds almost wholly interfered with observations.

5. A group of Sunspots of unusual dimensions was frequently observed and sketched during its period of visibility, September 3–15. The observations of September 15 have been communicated to the Society.

Preparations had also been made for photographing the *Leonids*, November 13–16, but except on November 13 observations were impossible owing to fog or cloud. On November 13, though a good deal of fog prevailed, yet stars of the 4th magnitude could be seen within about 20° of the *Sickle*, at intervals between $16^h\ 10^m$ and $18^h\ 0^m$, when increasing fog put an end to all observations. During this interval three meteors were seen, of which only one seems to have been a *Leonid*.

During the year a large chronograph of Sir H. Grubb's now well-known pattern, similar to that constructed by him for the Royal Observatory, Cape of Good Hope, and for the Perth Observatory, W. Australia, with some improvements which experience has suggested, has been ordered and is now approaching completion.

Some improvements in the eye-pieces of the Transit Circle have been effected. A new clamp and slow-motion apparatus to

work directly on the axis is in process of construction by Messrs. Troughton and Simms.

A recording micrometer eye-piece has also been ordered from the same firm.

The volume of Radcliffe Observations, containing the results of the astronomical and meteorological observations for the years 1890 and 1891, has been printed, with the exception of the introduction, and will soon be ready for publication and distribution.

A list of recent Radcliffe Observations of red and reddish stars has been forwarded to Mr. G. F. Chambers at his request.

The meteorological observations and automatic registrations have been regularly maintained as usual, and the results have been communicated to public institutions as well as to private inquirers.

The underground platinum resistance thermometers continued to give us considerable trouble in the earlier part of the year, serious discrepancies occurring in readings taken with them. After a long series of observations and experiments, these discrepancies were traced to uncertainties in the contacts at the switchboard, and to a want of thorough insulation in the leads. In October new leads of an improved kind were attached to the thermometers, and means were taken to ensure more perfect contact at the switchboard. Since then the instruments seem to have been performing in a thoroughly satisfactory manner.

University Observatory, Oxford.

The present work of the Observatory is a share in the International Astrographic Chart. To the measurement and reduction of the Catalogue plates it was decided to devote five years, and application was made to the Government Grant Committee for 150*l*. a year during this period, so that computers (of ages ranging from 15 upwards) might be employed on the work. Half this grant has now been spent, and 466 plates of the total 1180 are completely measured and reduced. When it is remembered that some time was spent in getting the work into shape; that some of the early work has been repeated with improved conditions; and that there is a considerable amount of preliminary computing for other plates in hand, as well as a number of plates measured but only partially reduced, we may hope that the remaining portion of the work will practically be completed in the time and for the money estimated. At the same time it must be remarked that it will be only the bare bones of the work; and that in the course of the straightforward measuring and reduction, many important investigations naturally suggest themselves which have for the present been put aside, but which it is hoped to take up after the plates are all measured. Five computers were employed in the first half of the year; three since then; Mr. T. J. Moore, of the Leeds

Astronomical Society, having also measured at his home near Doncaster with an instrument lent him by the Observatory.

Altogether 155,000 measures have been made during the year, 56,000 by Mr. Moore, and 99,000 at the Observatory. [All the reductions, including the comparison and revision of Mr. Moore's measures, are done at the Observatory.] Since each plate is measured twice, this means 77,500 star positions, or about 30,000 separate stars. The number of plates measured was 226, giving an average of 344 stars per plate, still higher than last year's average of 290. Thus, in spite of the procedure detailed in last year's report, the work is steadily exceeding our expectations. The preliminary counting of the stars on a plate, as proposed last year, has been carried out by the use of a hand billiard-marker, which allows the observer to record the count with one hand without removing his eye from the microscope with which he is reviewing the plate. This counting has been found very useful in selecting satisfactory plates.

During the latter half of the year comparatively little measuring was done at the Observatory, the time being devoted to completing the reductions of plates already measured.

Forms have been prepared, and bound in six large volumes, for showing the corrections to the Cambridge A. G. Zone Catalogue indicated by the Oxford photographic measures. The residuals form a most interesting study. One fact appears immediately, viz., that the residuals for N.P.D. are much smaller than those for R.A., and it becomes a question whether, in deducing the constants of a plate, double or treble weight shall be given to the N.P.D. observations. Such points as these must, however, be reserved for complete discussion. The methods of reduction employed allow this reservation without sensible waste of work.

It may be mentioned that we have found the plan of storing plates in envelopes, as at Harvard, a great advance on the plan of grooved shelves previously adopted.

Mr. Bellamy has devoted his energies to this work as thoroughly as before, and the best thanks of the Director are due to him.

The usual lectures on mathematical astronomy were given during the year. A candidate presented himself for examination in the Final School of Astronomy last June, and obtained a first class.

The Director took part in the observation of the Total Eclipse of the Sun in India last January.

Temple Observatory, Rugby.

The educational work of this Observatory has been carried on as usual, and members of the school have been present on fifty evenings. The remaining time available has been given up to the measure of double stars.

For the last two years a portion of the Observatory has been set apart for micro-photography, and some very fair results have been obtained by two members of the school.

Stonyhurst College Observatory.

The usual work of the Observatory, both meteorological and magnetical, has been carried on as already described in *Monthly Notices*, 1896 February.

Drawings of the solar surface have been made on 158 days, and spectro-photographs of the H–K region with the grating spectrograph on 50 days, with two to five exposures on each day, according to the circumstances of the day. These are being collated, and the results will either appear in our annual volume or be presented to the Society's *Monthly Notices*.

The evening skies have been more than ever unfavourable for the stellar spectrograph, and the total number of plates exposed does not exceed 105. This number represents work in the earlier hours of the nights, with an average exposure of about one hour, work in the later hours, or small hours of the morning, being generally incompatible with other obligations.

The sky was completely overcast during the nights of the November meteors.

The Lunar Eclipse of December 27 was well seen, and the observations made have been presented to the *Monthly Notices*.

Dr. Common's Observatory.

Very little astronomical work has been done during the past year. A twelve-inch telescope has been made on the plan of having a large flat placed at an angle of 45° with the axis of the large mirror, a few inches within the focus, and viewing the image through a perforation in the large plane. Owing to the difficulty of working a large oval plane, the performance was not quite perfect, but the absence of any rays round the images of stars, and the blackness of the field of view, were very pleasing. It is intended to complete this instrument with a perfect plane. Further experiments with the Brachy form of telescope have been carried on, but are not yet completed.

Markree Observatory (Colonel Cooper's).

During the year 1898 Mr. F. W. Henkel has been appointed to undertake the duties of observer at this Observatory, and the work has been mainly confined to the usual routine of meteorological observations and reductions.

In November the clockwork and the other parts of the great

refractor (13 in. aperture, 25 ft. focal length) were cleaned and put into fair working order by local workmen, the meridian circle also was cleaned as far as possible; both instruments have got into a rather bad condition, through disuse and the severity of the weather. It is hoped to make some definite observations with the refractor, but the unfavourable condition of the atmosphere and continual cloudy skies will be a serious drawback in the way of continuous observation. The library, which was in a rather chaotic condition, has been arranged, and is being catalogued.

A free public lecture on astronomy, which was fairly well attended, was delivered in the neighbourhood, and it is proposed to deliver a few further lectures later on, should there appear to be any interest in the subject. The Observatory has been visited by various local amateurs, clergymen, and others; and it is the desire of the director to render any assistance in his power to those who take an interest in the science of astronomy.

A magnetometer and dip circle (both instruments in good condition) having been found in the Observatory, it is proposed to start observations of the magnetic elements in the neighbourhood, as well for the determination of secular changes as for confirmation of the magnetic surveys of Professors Rücker and Thorpe, so far as relates to the immediate neighbourhood. For this purpose a short visit has been made to the Kew Observatory, where, by the kindness of Dr. Chree and his chief assistant, Mr. Baker, valuable information and instruction have been obtained.

Professor Turner, of the University Observatory, Oxford, has kindly lent a model of his plate-measuring machine, and also some "Pleiades" plates, taken under the direction of the late Professor Pritchard, and these plates are being measured on the same plan as that adopted at Oxford, Greenwich, and elsewhere.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

The work of this Observatory during the year 1898 differed in no respect from that of recent years. The planets *Jupiter* and *Mars* were regularly observed, and measures of a selected list of close binary stars were made. The usual meteorological observations were made, and monthly reports sent to the Registrar-General and others.

Wolsingham Observatory (Rev. T. E. Espin's).

The sweeps for stars with remarkable spectra have been continued on the same lines as in former years. The total number of hitherto unrecorded objects found during the year is 334, made up as follows :—

II. or III.	217
III. !	37
III. !! or III. !!!	78
IV.	2
	334

Various plates have been taken with the 8-inch photo-telescope during the year.

Sir William Huggins's Observatory.

At the Tulse Hill Observatory during the past year the photography of the spectra of stars, which has been in progress for some years, has been continued.

Work has also been done in the laboratories, especially in connection with the results which have been obtained from the photographed star spectra. These, together with an atlas of representative spectra, will, it is expected, be ready for publication in a few months.

Rousdon Observatory, Lyme Regis, Devon
(Sir Cuthbert E. Peek's).

The building and the equipments of the Observatory have been maintained in their usual order. January was an abnormally cloudy month, but with this exception weather has been very favourable, and observations have been made on 162 nights; this is about the average. The 6·4-inch equatorial has been kept at the regular observation of long-period variable stars; Argelander's method is followed as during the previous twelve years. 547 magnitude determinations have been made; this is somewhat above the average number. Twenty-three maxima and sixteen minima have been observed. Twenty-five long period variables are under regular observation; these being mostly circumpolar, the light variations are continuously recorded.

Variable Star Notes No. 3 has been recently published and distributed. This contains the observations of *S Cassiopeiæ* and *S Ursæ Majoris* for the ten years 1887 to 1896. The results are given concisely in tabular form, accompanied by diagrams of the light curves. *Variable Star Notes* No. 4 is far advanced, and will appear shortly.

Transits of stars have been taken as often as required for the rating of the sidereal clock, which has maintained a very steady rate.

Dr. Isaac Roberts's Observatory, Crowborough Hill, Sussex.

The work done at this Observatory during the past year will be estimated by the following list of selected photographs, which have been taken with the 20-inch reflector and the 5-inch camera

lens, and is given, in continuation of similar lists which have been published in the *Monthly Notices*, vol. lviii., pp. 187–89, and in the volumes for the previous years.

Reference was made in the report for last year to the necessity of printing in permanent form some of the valuable photographs that have been taken with the 20-inch reflector during the past few years, so as to make them available for scientific investigation. This work has been closely pursued in the past year, and a number of enlarged photographs, together with the descriptive matter relating to them, as well as deductions founded upon the evidence which they furnish, are now nearly ready for the press, and a volume will be issued in due course.

The weather of the past year has been exceptionally bad for celestial photography.

List of the principal Photographs taken in 1898.

	R.A. h m	Decl. ° ′	Expos. m
♅'s Nebulous Region No. 5 ...	0 30	+23 35	90
Neb. ♅ I. 157 Trianguli	1 42	+26 55	2h 30m and 2h 42m
Neb. ♅ I. 158 Eridani	4 26	− 5 18	52
Region in Perseus	4 26	+50 44	71
Neb. M. 42 Orionis	5 30	− 5 27	40
Neb. ♅ IV. 33 Orionis	5 31	− 6 47	60
Neb. ♅ IV. 38 Monocerotis ...	6 5	− 6 15	60
Nebula in Monoceros	7 0	−10 20	2h 10m
Nebulæ near α Geminorum ...	7 25	+31 38	90
Neb. ♅ V. 44 Camelopardi ...	7 27	+65 50	90
"Leonid" radiant	9 58	+22 52	90, 1h 48m, 1h 49m, 2h
Neb. ♅ I. 199 Ursæ Majoris ...	10 13	+46 6	70 and 2h 20m
Neb. ♅ IV. 6 Sextantis	10 46	+ 6 26	90 and 2h 51m
Neb. ♅ I. 233 Ursæ Majoris ...	10 48	+54 52	90
Neb. ♅ I. 87 Leonis Minoris ...	10 55	+29 33	2h 5m
Neb. ♅ II. 730 Ursæ Majoris ...	11 28	+47 38	90
Neb. ♅ I. 213, 212 Can. Ven. ...	12 23	+45 0	[illegible]
Neb. ♅ I. 197–8 Can. Ven. ...	12 25	+42 15	90 and 2h
Neb. M. 51 Can. Ven.	13 25	+47 45	90
"Leonid" meteor swarm	13 50	− 1 36	2h
" " " ...	14 6	− 3 15	2h
Neb. ♅ I. 215 Draconis	15 3	+56 10	90
Cl. M. 13 Herculis	16 38	+36 40	60
Cl. ♅ VIII. 72 Serpentis	18 22	+ 6 30	90
Neb. M. 57 Lyræ	18 50	+32 54	20 and 60m
Hind's neb. in Aquila	19 6	+ 0 52	2h 55m

	R.A.	Decl.	Expos.
	h m	° ′	m
Neb. ♅ IV. 14 Aquilæ	19 9	− 2 54	90
Neb. ♅ IV. 51 Sagittarii ...	19 38	−14 24	60
Neb. ♅ IV. 73 Cygni	19 42	+50 16	90
Stars in Cygnus	19 45	+35 30	$2^h\ 35^m$
Cl. M. 71 Sagittæ	19 49	+18 30	90
Neb. ♅ IV. 72 Cygni	20 8	+38 5	$2^h\ 53^m$
Neb. ♅ IV. 13 Cygni	20 12	+30 15	2^h
Planet DQ 1898 (Eros)	20 39	− 6 0	51 and 60
Neb. ♅ IV. 74 Cephei	21 0	+67 45	90, $1^h\ 43^m$, $2^h\ 54^m$
♅'s Nebulous Region, No. 48 ...	21 34	+10 19	90
" " " " 50, 51 ...	22 57	+25 45	90
Neb. ♅ IV. 52 Cassiopeiæ ...	23 16	+60 37	$1^h 47^m$ and $2^h 50^m$
Cl. ♅ VI. 30 Cassiopeiæ	23 52	+56 9	90

Mr. W. E. Wilson's Observatory, Daramona, Streete, co. Westmeath.

During the past year the 2-foot reflector has been used exclusively for photography. A certain weakness in the collimation of the reflector and its 6-inch guiding telescope has been traced to the supports of the mirror and its cell. A much heavier and more rigid cell has been supplied by Sir Howard Grubb, which seems to have cured the evil.

In August a cinematograph photograph was taken of a Sun-spot. A photograph was taken at the rate of about 100 exposures in the hour on a roll of film, and continued for about four hours. Unfortunately the spot was not a very large one and did not show much change in the four hours, but the experiment showed the feasibility of the method when a large and active spot is on the disc.

The 'Main' heliostat was used for the measurement of the radiation from the great Sun-spot in September. It proved to be the darkest spot yet measured.

Experiments are being carried on with a new form of solar radiation instrument.

Adelaide Observatory.

The staff was the same as during 1897. Only one of the vacancies caused by the retirement of Mr. W. E. Cooke (now Government Astronomer at Perth, W.A.) and the death of Mr. Sells has been yet filled up. We have been shorthanded, and our work has consequently fallen somewhat into arrear or has had to be curtailed.

With the transit circle the regular work has been the continuation of the observation of Fiducial Stars for the *Melbourne Photographic Durchmusterung.*

For this work we have made 782 observations of R.A. and a similar number of N.P.D.

For time purposes 1,020 Clock Stars were observed.

For instrumental corrections :—

Determinations of Level Error . . .	85
„ „ Azimuth . . .	146
Readings of Collimation	104
„ „ Nadir Point	116

Repairs to the Observatory buildings in October and November interfered somewhat with the transit work. Owing to reduced staff no other work could be undertaken with the transit circle or the equatorial.

The meteorological work of the Observatory is very heavy and occupies much of our time. It includes the daily publication of weather reports from all the telegraph offices in the colony and selected stations in the other colonies, also daily forecasts. The volume for 1896 has been published during the year, and 1897 is now passing through the printer's hands.

The R.A. micrometer wires of the transit circle were accidentally broken on May 26, but were renewed on the 27th.

Hong Kong Observatory.

Hourly meteorological observations, weather reports, and storm warnings, magnetic observations, tabulation of meteorological observations made over the eastern seas, the time-service, &c., were continued as in previous years. 275 typhoons in all have now been investigated, and the laws of storms completely mapped out. 15-year meteorological and magnetic reports have been prepared, and will be printed in the fifteenth volume of observations and researches.

The observations made to determine the latitude were reduced last spring, and furnished a value of the latitude with a probable error of $\pm 0''\cdot 016$ on the A.G.C. system, and a value of the constant of aberration with a probable error of $\pm 0''\cdot 040$. The former was the smaller, as the observations were arranged with the object of determining the latitude accurately without regard to the determination of a new value of the aberration. Chandler's forecast of the changes in the latitude was substantiated. The accuracy of the observations was found to depend upon the magnitudes of the stars. Such is probably the case with all determinations of right ascensions and declinations, which for each instrument are most accurate in case of stars of a

certain magnitude and less accurate for other, especially fainter, stars.

Southern variable stars were observed during the first portion of the year with a binocular. Orbits of *Castor*, Σ 228, OΣ 387 and OΣ 400 were calculated. The Zodiacal Light was occasionally observed, as has been done since 1895. Meteors were observed in November. Progress has been made with a re-reduction of Sir J. Herschel's sequences of southern stars, which are very accurate, but great difficulty was experienced in identifying the stars, notwithstanding the work previously done by Gould and his assistants.

With the small transit instrument about 2000 transits were observed, mostly in autumn, and mostly of low southern stars; 2000 of which, not often observed previously, have been selected of between the sixth and seventh magnitude for continuous observation here. It is intended to base a catalogue of right ascensions on these transits when each star has been observed eight times—four times in each position of the instrument. The right ascension observed is at once compared with the corresponding value in Stone's Catalogue, and if the difference exceeds a quarter of a second (in time) a value of the proper motion is determined from all the observations contained in catalogues to which we have access. The reduction of every observation of any kind is finished not later than the spring of the following year.

Madras Observatory.

The Observatory took part in the observations of the total eclipse of the Sun in January. The station occupied was Sahdol, and two series of good negatives of the corona were obtained, one with a 40-foot camera, the other with a 5-foot camera.

The MS. of the *New Madras Star Catalogue* was completed in August, and about one-third of it was in type at the close of the year. The rate of printing is slower than was expected, as the Government Press has been overwhelmed with urgent work connected with the measures taken to fight the plague.

The usual time service was maintained, and it was extended to the two railway systems terminating in Madras. Observations of the *Leonids* were made, and communicated to the director of Harvard College Observatory. Observations were also made of stars occulted during the total eclipse of the Moon in December.

The new buildings for the Observatory at Kodaikánal have made considerable progress, in spite of opposition from an unexpected quarter, which delayed work for nearly six months. The headquarters of the Observatory will move to Kodaikánal early in 1899, when the postal address will be :—

Kodaikánal, Palani Hills, South India.

Melbourne Observatory.

The astronomical work has consisted almost solely of observations with the 8-inch transit circle, and astrographic operations. Only very few occasional observations have been made with the Great Telescope and 8-inch equatorial, principally on comets; and the photoheliograph was used on 37 days only for photographing the Sun on special occasions. The members of the Victorian branch of the British Astronomical Association, and some of the members of the Observatory staff, were organised for the purpose of systematically observing the expected meteoric shower of *Leonids*; but the nights of November 12, 13, and 16 were cloudy between 1.30 A.M. and 4.15 A.M., and the nights of November 14 and 15 were partially cloudy at intervals between these hours. On the morning of the 14th 12 meteors were observed, only two of which were classed as *Leonids*, and on the morning of November 15 13 meteors were seen, only 6 of which were classed as *Leonids*.

The time service, the meteorological service, the continuous photographic registration of the magnetic elements and absolute measurements of these elements, the rating of chronometers and testing of nautical, meteorological, and surveying instruments, and other miscellaneous work for the public, were carried on as in previous years. Cloud photography was continued throughout the year. A commencement has been made in measuring the plates of the *Astrographic Catalogue* for the regions allotted to the Australian Observatories.

The reduction of the magnetic curves which cover an uninterrupted period of about 30 years has also been initiated, and the third Melbourne Catalogue for the Epoch 1890, embracing all observations made with the 8-inch transit circle from 1884 to 1893 inclusive, is now in course of preparation.

The following are the details of the astronomical work.

Transit Circle Observations :—

Observations in Right Ascension.		*Observations in North Polar Distance.*	
Clock stars	692	Circumpolar stars ...	142
Azimuth stars ...	328	List stars	1173
List stars	1190	Total...	1315
Total	2210		

Observations for Level	100
" " Collimation	116
" " Nadir	97
" " Runs	48
" " Flexure	13

The list stars were selected, as in previous years, from the plates of the *Astrographic Catalogue* (Melbourne portion), which are

to be used for forming the standard co-ordinates in the reduction of these plates. The total number of stars required for this purpose will be at least 6,000, of which some 3,700 have now been observed three times or more. The Adelaide Observatory has continued to assist us in the observations of these stars.

Astrographic :—

182 chart plates with single exposure of one hour were taken, examined and passed as satisfactory.
25 chart plates were taken; but rejected owing to broken exposure, faults in the film, or defective setting.
5 catalogue plates (duplicate) taken for experiments in measuring.
31 plates taken in the region around the South Pole for testing definition, transparency, &c.
9 plates for the Oxford type charts for standards of magnitude.
22 plates for trails, for adjustment of orientation.
13 plates for scale values, adjustment of centre of plates, and other instrumental adjustments.
2 photographs of comet *Coddington*, one hour exposure.
1 photograph of κ *Crucis* } three hours' exposure.
1 „ „ ω *Centauri* }

The total number of chart plates now passed as satisfactory is 354. From 296 catalogue plates 1,505 stars were selected, measured and approximately reduced for observation with the transit circle. The Governments of New South Wales and Victoria having agreed to the proposals made in a joint memorandum by the Directors of the Sydney and Melbourne Observatories, regarding the measurement of the Australian plates of the *Astrographic Catalogue*, which proposals were briefly mentioned in last year's Report, six young ladies were accordingly selected for the purpose out of a great number of applicants, and they commenced their training at this Observatory on November 1. It would be premature to say more about the organisation and efficiency of this measuring bureau at present, beyond the mere mention of the fact that these ladies, or at least the majority of them, are now quite able to discharge their duties, although much more experience will be necessary before the work can proceed at a satisfactory rate.

Lovedale Observatory, South Africa. (*Mr. A. W. Roberts.*)

Observations of variable stars south of −30° were resumed in August. The work done during the last five months of the year is as follows:

Algol variables (4 stars)	154 observations,
Short period variables (20 stars) ...	632 observations,
Long period variables (62 stars) ...	534 observations.

This does not include observations of suspected variables, of which, however, there have been but few.

Besides the regular observation of known southern variables, a commencement was made of a survey, by eye-estimates, of the brightness of all stars between $6^m \cdot 8$ and $9^m \cdot 2$ south of $-30°$.

The proposed plan of work may be briefly described as :

(1) A determination of the visual brightness of a network of $6^m \cdot 8$ stars, the magnitudes to be determined when the stars are at the same altitude, viz. that of the S. pole at Lovedale.

(2) A similar determination of the brightness of a network of $9^m \cdot 2$ stars.

(3) To these standard $6^m \cdot 8$ and $9^m \cdot 2$ stars all the other stars south of $-30°$ are referred.

As far as already gone the method of securing the necessary $6^m \cdot 8$ standard stars has been to begin with L 6460 (Dec. $-89° 25' \cdot 5$: assumed mag. 6·8), and working round the sky at an altitude of 32°, to reach L 6460 again.

It is expected that the survey will be completed in fifteen years.

Mr. Tebbutt's Observatory, The Peninsula, Windsor, New South Wales.

In consequence of the very large proportion of clear evenings during the winter months, a large amount of work was accomplished for the year 1898. The following is a summary of the work for the determination of local time :—

Nights on which the time was determined	... ...	168
Stars observed with a declination not exceeding 40°	...	788
Stars of high declination observed for azimuth	...	193
Separate determinations of { level error	... ...	447
Separate determinations of { collimation error	...	42
Separate determinations of { azimuth error	... ...	142

The adjustments of the transit instrument were unusually steady during the year, and in this respect form a contrast to those of 1897. By means of the filar and square bar micrometers on the equatorials the following comparisons were obtained :—

Object.	Nights of Observation.	Number of Comparisons.	Number of Comparison Stars.
(4) Vesta	6	73	3
(7) Iris	16	211	3
(42) Isis	8	107	4
Jupiter and η Virginis	7	91	...
Uranus and ω¹ Scorpii	10	132	...
Uranus and ω² Scorpii	10	132	...
Encke's Comet	2	6	4
Comet Coddington-Pauly	80	612	105

Encke's comet was found on June 11. It was well seen with the $4\frac{1}{2}$-inch equatorial, although close to the band of twilight along the horizon. After June 15 the comet, contrary to expectation, rapidly became expanded and diffused, so that no further micrometer observations could be made. The accepted formula for the computation of the apparent intensity of a comet's light altogether fails in the case of this interesting object. The cable message announcing the *Coddington-Pauly* comet reached the Observatory on June 14. The first position obtained was on the 15th, and from that date to the close of the year the comet was observed on all possible occasions. The series of positions obtained is a record one as respects this Observatory. The comet 1892 VI. (Brooks) was observed on sixty-two nights, extending over the period 1892 November 28 to 1893 June 19. It is quite possible that the present comet will be visible in the 8-inch telescope till the Moon again comes into the western sky, but after the January full Moon there will be no prospect of getting further observations. I am indebted to several astronomers for ephemerides of this object, especially to Mr. C. J. Merfield, of Sydney, who has from time to time furnished me with predicted positions down to March 14, 1899, based on elements derived by himself from extended local observations. He informs me that the orbit is probably a hyperbola. Attempts were made to observe the two comets *e* and *h* 1898, discovered by Perrine, but the difference of right ascension of the Sun and the comets was not sufficiently great to admit of either comet being seen on a dark sky.

Besides the observations already enumerated, the disappearances of thirty-six stars, almost all of which are well-determined objects, were observed with the large equatorial. Phenomena of *Jupiter's* satellites were also observed, and a few comparisons of *R Carinæ* made.

It will be seen from the preceding summary of the work for 1898 that the reductions have been unusually heavy, and, unfortunately, nearly the whole of this work, in consequence of the extreme difficulty in obtaining the occasional services of a trustworthy computer, has devolved on the observer himself. In conclusion, it may be stated that the daily rainfall and monthly maximum and minimum temperatures have been recorded, and that the complete meteorological observations for the period 1891–1897 have been published and distributed since the last report in the *Monthly Notices*.

Notes on some Points connected with the Progress of Astronomy during the Past Year.

Discovery of Minor Planets in 1898, (including that of Eros).

Fifteen new planets were discovered during the past year, as follows :—

Provisional Designation.	Permanent Number.	Name.	Date of Discovery, 1898.	Discoverer.	Place of Discovery.
DP	...	...	July 16	Charlois	Nice
DQ	433	Eros	Aug. 13	Witt	Berlin (Urania Obs.)
DR	434	Hungaria	Sept. 11	Wolf	Heidelberg
DS	435	...	11	Wolf—Schwassmann	„
DT	436	...	13	Wolf—Schwassmann	„
DU	...	...	Nov. 8	Charlois	Nice
DV	...	...	6	Wolf—Schwassmann	Heidelberg
DW	...	...	6	Wolf—Villiger	„
DX	...	...	6	Wolf—Villiger	„
DY	...	...	13	Wolf—Villiger	„
DZ	...	...	19	Wolf—Villiger	„
EA	—	...	19	Wolf—Schwassmann	„
EB	...	...	Oct. 13	Coddington	Mt. Hamilton (Lick Obs.)
EC	...	...	13	Coddington	„
ED	...	...	Dec. 8	Charlois	Nice

The following planets discovered in 1897 have received permanent numbers since the date of the last report ; DL 429, DM 430, DN 431, DO 432.

The following planets have been observed at a second opposition since the date of the last report : 397, 409, 416, 418, 420.

The astronomical sensation of the year has been the discovery of the planet (433) *Eros*. The orbit of this planet is altogether unique, its mean distance from the Sun being 1·458, or considerably less than that of *Mars* (1·52). As the eccentricity is 0·223, the perihelion distance is 1·133, and the least distance from the Earth's orbit only 0·149, which is little more than

half that of *Venus* in transit. The planet will therefore be of immense value in the determination of the solar parallax.

The following orbit by Professor Chandler is the most accurate yet published; it is based on observations extending from the date of discovery to November 26, combined with four places found by examining the plates taken at Arequipa in 1896.

Epoch 1898 Aug. 31·5 G.M.T.

$$
\begin{array}{lll}
M & = 221^{\circ}\ 35'\ 45''\!.6 & \\
\varpi & = 121\ \ 9\ 53.1 & \left.\begin{array}{l}\\ \\ \\ \end{array}\right\} 1898.0 \\
\Omega & = 303\ 31\ 57.1 & \\
i & = \ 10\ 50\ 11.8 & \\
\phi & = \ 12\ 52\ \ 9.8 & \\
\mu & = 2015''\!.2326 & \\
\log a & = 0.1637876 & \\
\text{Period} & = 643.10 \text{ days} &
\end{array}
$$

Using an ephemeris from these corrected elements, the plates taken at Harvard in 1893–94 were carefully examined by Professor Pickering and Mrs. Fleming, and the planet has been found on seventeen plates, the dates ranging from 1893 October 28 to 1894 May 19. The greatest error of the ephemeris is 8 sec. in R.A., 1′ in Decl., so that the above elements are probably very near the truth. This opposition of 1894 was practically the most favourable possible, opposition and perihelion almost synchronising. An equally favourable opposition will not occur till 1931; the next opposition, which will occur in 1900 November or December, will be the best that we shall have till then, and it is to be hoped that it will be fully utilised for parallax observations. Unfortunately, the planet's high north declination will place it practically out of reach of the observatories of the southern hemisphere. The following approximate ephemeris for Greenwich midnight, deduced from the above elements, will give some idea of the circumstances:—

	R.A. h m s	N. Decl. ° ′	Δ	Magnitude
1900 Nov. 10	1 56 24	54 23	0·3747	9·38
18	1 41 8	53 37	0·3535	
26	1 30 40	51 52	0·3383	9·07
Dec. 4	1 26 32	49 26	0·3268	
12	1 29 22	46 23	0·3200	8·88
20	1 38 48	43 5	0·3162	
28	1 54 28	39 39	0·3154	8·78
1901 Jan. 5	2 14 34	36 12	0·3176	
13	2 38 6	32 45	0·3119	8·78

The above magnitudes take no account of phase, the effects of which are, however, very sensible; for as seen from *Eros* the

elongation of the Earth from the Sun may amount to 60°, and at such a time only $\frac{3}{4}$ of the apparent disc of *Eros* would be illuminated. Special precautions would seem to be advisable to prevent this unsymmetrical illumination of the disc from causing systematic errors in the parallax.

The diameter of *Eros* is perhaps some seventeen miles, in which case its disc would subtend an angle of 0″·25 at the most favourable opposition, and 0″·12 at the coming one.

It may be of interest to give an abridgment of Professor Chandler's ephemeris for 1893-94 (for Greenwich midnight), both in the hope that other photographs may be found now that the accurate place of the planet is known, and to illustrate the very singular fact that at a perihelion opposition the planet does not retrograde in longitude; its linear velocity exceeding that of the Earth.

	R.A. h m	N. Decl. °		R.A. h m	Decl. °	
1893 Oct. 27	5 56·4	53·3	1894 Jan. 31	7 23·6	14·3	N.
Nov. 8	6 31·7	55·8	Feb. 12	7 27·6	2·6	N.
20	7 4·3	57·4	24	7 39·3	4·9	S.
Dec. 2	7 30·5	57·7	Mar. 8	7 56·7	9·2	
14	7 45·3	56·1	20	8 18·5	11·6	
26	7 46·7	51·6	Apr. 1	8 43·4	12·8	
1894 Jan. 7	7 38·0	42·6	13	9 10·6	13·5	
19	7 27·8	29·0	25	9 39·3	14·0	S.

The planet (434) *Hungaria* is also a very interesting one, for, excluding (433) *Eros*, its mean distance 1·947 is much less than that of any other member of the group. The following elements are by Dr. Berberich (*Ast. Nach.* 3525):—

Epoch 1898 Oct. 10·5, Berlin M.T.

$$\begin{aligned} M &= 58^\circ\ 46' \\ \omega &= 123\ \ 10 \\ \Omega &= 174\ \ 38 \\ i &= 22\ \ 34 \\ \phi &= 4\ \ 15 \\ \mu &= 1306''\cdot 4 \\ \log a &= 0\cdot 2893 \end{aligned}$$

Perihelion distance 1·802

The planet EC has also a small mean distance, coming about 17th when the group is arranged in order of ascending mean distance.

A. C. D. C.

The Comets of 1898.

The re-discovery of Winnecke's comet was mentioned in the last Annual Report. Omitting this re-discovery, no less than seven new comets have been found, and two of elliptic orbit observed at their return to perihelion.

On March 20 Mr. C. D. Perrine detected a tolerably bright comet in the constellation *Pegasus*. The head was described as a nebulosity 2′ in diameter, containing a central nucleus of 10″, and the comet possessed a tail a degree in length. Photographs taken at Northfield Observatory showed the existence of two tails, one straight and narrow, nearly two degrees in length, turned directly away from the Sun, and a shorter curved tail, which might correspond to the hydrocarbon type. The definitive elements of the orbit have not yet been determined, but Mr. Perrine, using about six weeks' observations, found deviations from parabolic motion, and suggested a period of 305 years. This suggestion is confirmed by MM. Berberich and Pokrowskij, who assign a period of 322 years, and point out that at the descending node the comet approaches the orbit of *Jupiter* within 1·3 R, which might explain the origin of the elliptic motion. Mr. Perrine also calls attention to a general similarity between the elements and those assigned to the comets of 1684 and 1785 I., as shown below :—

	1684.	1785 I.	*b* 1898.
ω	330°·3	205°·7	47°·6
☊	268·2	264·2	262·5
i	65·4	70·2	72·4
q	0·958	1·143	1·094

Since observations were continued far into the summer, a good opportunity will be afforded for determining the mean motion of the comet, and settling the question of identity or connection. The discrepancies in the value of ω are opposed to the suggestion.

On June 9 Mr. Coddington, of the Lick Observatory, exposed a photographic plate, which, on development on June 11, disclosed the trace of a fairly conspicuous comet. The same object was independently discovered by M. Pauly, of the Bucharest Observatory, who detected it with a 3-inch telescope. The comet had very considerable south declination at the time of discovery, and since this element was increasing, observations in Europe were necessarily few. In the early days of July the comet had sunk below the horizon of Central Europe. But valuable series of observations have been made in the southern hemisphere, where up to the end of the year the comet was still distinctly visible in a 6-inch telescope. It is not impossible that the comet

will be re-observed in the northern hemisphere in the coming spring, when its northerly motion will again bring it above our horizon. The observations up to the present are well represented by a parabola.

The calculation of the circumstances of the return of Encke's periodic comet has been entrusted to M. A. Iwanow, who supplied an ephemeris which he believed would not be in error by more than three minutes of arc. As a matter of fact, the comet was found by Mr. Tebbutt, of Windsor, N.S.W., on June 11; the error of the predicted place being very slightly larger than that assigned by the computer. The credit for re-discovery is shared with Mr. J. Grigg, of Thames, New Zealand, who saw the comet on June 7, guided by the results of his own calculations. By Mr. Tebbutt's account the comet appears to have been a very difficult object for observation, and but few places are likely to be secured at this apparition.

The next comet, first seen on June 16 by Mr. Hussey, of the Lick Observatory, was that of Wolf, which was discovered in 1884 and again observed on its return in 1891. The circumstances of the return in this year were not very favourable for observation, as the elongation of the comet from the Sun remained for a long time very small, and but for the admirable ephemeris supplied by the Rev. A. Thraen would not have been detected so early in the year. By Mr. Hussey's observation, the computed place was shown to be in error only -1 sec. in R.A. and $+4''$ in declination, scarcely more than the errors of observation. One cannot withhold a tribute of admiration for the brilliant and accurate results that have followed M. Thraen's investigation into the motion of this comet, and of regret and sympathy that failing eyesight compels him to restrict his astronomical researches. The motion of the comet carried it very near to the planet *Mars*, and on July 19 micrometrical measurements of the distance between the comet and the planet were effected by M. Abetti, of the Arcetri Observatory. The comet is probably still under observation in large telescopes.

Mr. Perrine added another to his long list of cometary discoveries by detecting, on June 14, a faint telescopic comet in the constellation *Perseus*. It was described as having equal brilliancy with a star of the tenth magnitude, and proved to be increasing in brilliancy as it approached the Sun, the perihelion passage taking place on August 16. Curiously enough, the elements of the orbit also showed some similarity with those computed for the comets of 1684 and 1785 I., already quoted, and also those of comet *Pons-Brooks*, 1812–84. The deviation in the perihelion distance between the earlier comets and the new one is considerable. The most trustworthy orbit yet published appears to be that due to Mr. Perrine, which is as follows, and can be compared with the quantities given in an earlier paragraph, and also with that of 1884 :—

	Perrine.	Comet Pons-Brooks, 1884.
	° ′	° ′
ω	205 36	199 15
☊	259 6	254 6
i	70 1	74 3
q	0·6265	0·7752

There is at present no reason to suspect ellipticity. Shortly after perihelion passage, the comet passed out of reach of European observatories, but could still be followed in the Southern hemisphere.

On June 18 M. Giacobini, of the Nice Observatory, announced a new comet in *Capricornus*, which moved northwards shortly after its discovery. The object was faint, and does not appear to have been very freely observed. At Besançon, on July 9, the comet was described as exceedingly faint and the measures very difficult. The orbit will probably prove parabolic, and but little interest attaches to the comet.

Yet another comet fell to Mr. Perrine by a discovery on September 12. This object was fairly bright, comparable to a star of the eighth magnitude, and with a tail about fifteen minutes in length. The comet was independently discovered by M. Chofardet, at Nice, with a 3-inch telescope. The perihelion distance of this comet falls very close to the orbit of *Mercury*, and Mr. Perrine calculates that the two bodies actually approached within six million miles of each other. More accurate elements may vary this conclusion, but the perturbations produced by *Mercury* must be considerable. It will, therefore, be very interesting to compare the past perihelion places with those obtained near the time of discovery. Unfortunately, very few observations could be made before the comet was hidden in the Sun's rays, which rendered the comet invisible at the time of the greatest brilliancy. But by the middle of November, when the theoretical brilliancy of the comet will be about the same as at the time of discovery, there should be no difficulty in obtaining a good series of measures in the southern hemisphere.

An interesting comet was discovered on October 20 by Mr. Brooks, of Geneva, N.Y., in the constellation *Draco*. It was described as of good size, round, with a minute stellar nucleus. The comet moved southwards, rapidly diminished in brilliancy, and does not appear to have been observed after the end of November. The orbit, however, is sufficiently well determined to disclose a very distinct resemblance to that of 1881 IV. This latter comet was under observation for some months, and a very elaborate discussion of the elements was made by Dr. Stechert. He showed that while the most probable orbit was a hyperbola, the observations could be represented either by an ellipse of not less than 100,000 years, a parabola, or a hyperbola having an eccentricity expressed by 1·0003. There is, therefore, no possibility of the two objects being the same; but that they are moving in approxi-

mately the same plane, and are similarly situated, is shown by a comparison between the preliminary orbit assigned to Brooks' comet and Dr. Stechert's definite results.

	Brooks (Ristenpart)		Comet 1881 IV. Stechert.	
	° ′ ″		° ′ ″	
π	123 33 41	M. Eq. 1890·0	122 7 19	M. Eq. 1881·0
☊	96 20 1		97 2 37	
i	140 21 4		140 13 54	
log q	9·87852		9·80178	

The last comet of the year is assigned to Dr. Chase, of Yale, but simultaneous records of its appearance were secured in several observatories, though not clearly enough to warrant an announcement. Its discovery was due to an attempt to photograph the trails of the November meteors in the neighbourhood of the Leo radiant. Plates for this purpose were exposed at Yale, at Harvard, at Lick, and at Goodsell; and at each station, when attention was called to the fact, the comet was found to have photographed itself more or less distinctly. On November 21 Dr. Chase repeated his photographs of the suspicious object and clearly detected its cometary character. It is worth remarking that Dr. Chase swept over the district in which the comet was situated with an 8-inch refractor, but failed to find it. In fact, though increasing in brightness, the comet has always remained a faint object. The orbit will probably prove parabolic, and is characterised by a rather large perihelion distance. In computing the orbit Dr. Chase found it impossible to represent the observation of November 21, and is inclined to attribute the disagreement to a possible difference in the points taken for photographic and visual measurement.

Though this list of discoveries is unusually long, some other comets are known or suspected to have passed through perihelion undetected. Barnard's comet, observed in 1892, and found to have a period of 6·3 years, was due to return in April, but the circumstances were quite unfavourable to its re-discovery. Denning's comet of 1881, which returned in 1890 without being seen, has again escaped owing to an unfavourable position. Sweeping ephemerides of this comet were published without avail. A comet discovered by Swift in 1889, whose orbit is very uncertain, probably returned to the Sun this year, as also Brooks' comet of 1886, which has now completed two periods without observation. Tempel's comet of 1867 has suffered considerable perturbation since its discovery, and always in the direction of making its chance of detection more and more slender. It should have returned in October, but it may be seen when near opposition in the next few weeks.

W. E. P.

Progress of Meteoric Astronomy during the Year 1898.

Spectroscopic Analysis of Meteorites.—Numerous meteoric irons have been spectroscopically investigated by Messrs. Hartley and Ramage (*Proceedings Royal Dublin Society, VIII.* 68). They find that the composition of various meteoric irons offers a great resemblance. Meteoric irons, different varieties of iron ores, and manufactured irons contain copper, lead, and silver. Gallium is a constituent of meteoric irons, but not of all meteorites, and occurs in varying proportions. Sodium, potassium, and rubidium are also found in meteoric irons, but only in very small proportions. Meteoric stones, but not the irons, contain chromium and manganese. Nickel was found to be the chief constituent of all meteorites, meteoric irons, and siderolites, cobalt occurring in the last two varieties. Messrs. Hartley and Ramage describe the principal features of difference between telluric and meteoric irons to be the absence of nickel and cobalt in any considerable amount from the former, and the presence of manganese. Meteoric irons, on the other hand, contain nickel and cobalt as notable constituents, and except in minute cases manganese is absent. In referring to the photographic spectra obtained by Sir J. N. Lockyer from the Nejed and Oberakirchen meteorites the authors point out that, of the two lines, one described as unknown, and another as doubtfully ascribed to iron, the former is certainly, and the latter probably, a gallium line.

The Murranging Meteorite.—It is stated that this object, which weighs four tons, is on its way to England from Australia. Its destination is the British Museum, to which it has been presented by Mr. Bruce. The large Cranbourne meteorite is going back to Australia, it having been repurchased by the Colony of Victoria.

The Orbital Motion of the Leonids.—In *Ast. Nach.*, 3516, Dr. Abelmann, of St. Petersburg, gave some results of his computations of this meteoric stream. Adopting Hill's method, he divided the orbit into 36 parts of 10° of excentric anomaly, and computed the perturbations produced in the orbit of 36 parts corresponding to them. The total secular disturbances resulting in one $33\frac{1}{4}$-years period by the different planets were found to be as follows:—

	By Jupiter.	By Saturn.	By Uranus.	Sums.
$\delta\Omega$	$+22'\cdot4$	$+4'\cdot6$	$+0'\cdot8$	$+27'\cdot8$
δi	$+48''\cdot2$	$-33''\cdot6$	$-57''\cdot3$	$-42''\cdot8$
$\delta\pi$	$-2'\cdot3$	$-1'\cdot3$	$+0'\cdot1$	$-3'\cdot5$
δe	$+0\cdot00006$	± 0	± 0	$+0\cdot00006$

These results accord very closely with those of Professor Adams, who found a total disturbance of 28′, viz. *Jupiter* 20′,

Saturn 7′, and *Uranus* 1′. Dr. Abelmann remarks that it is probable the orbits of the meteors and of the parent comet (1866 I.) have nearly coincided with each other from a very remote time. The secular motion of the perihelion is about 1°·5 in 100 years, and as the stream has been observed for 1000 years, its line of apsides has revolved in that time 15°.

Perturbations of the Leonid Meteor Orbit since 1890.—Dr. A. Berberich (*Ast. Nach.*, 3526) has investigated the extent of recent disturbances exercised on the stream by *Jupiter*, *Saturn*, and *Uranus*. The influence of the latter planet was found to have been very small however. Dr. Berberich concluded that the sums of the perturbations impressed since 1890 on the meteoric groups expected in 1898 November and 1899 November were considerably larger than the secular orbit alterations alluded to by Dr. Abelmann. The displacements of the nodes are +52′ and +66′ for the two meteor groups, occasioning a corresponding lateness of 21 hours and 26 hours on their visible returns in the years 1898 and 1899 respectively. Dr. Downing independently undertook the computation of the disturbing effect of the larger planets upon the stream, and found that for the denser part encountered in 1866 there would be considerable retardation. Assuming that the section of the orbit to be crossed in 1898 had been similarly affected to that of 1866, the richest display must occur on November 15, at 17ʰ, and about 36 hours after the normal time. But the conditions indicated this as too late, and Dr. Johnstone Stoney, in calling the attention of astronomical observers and the public to these conclusions, announced that the shower would reappear either on the night following November 14 or 15, and most probably on the latter.

The Orbital Motion of the Bielid Meteors.—Dr. Abelmann remarks (*Ast. Nach.*, 3516) that the disturbing action of *Jupiter* in 1889·5–1891·5 produced a displacement of 4° in the node, as pointed out by Dr. Bredichin in 1892. This brought the shower four days earlier in that year than in 1872 and 1885. Dr. Abelmann points out that this meteor system can have suffered no sensible deformation by planetary attraction during the period from 1892 to 1898. But in 1901·2 the group will approach *Jupiter* to within about 0·5 of the Earth's distance from the Sun, and will be much deflected. This circumstance had been previously alluded to by Dr. Schulhof in 1894. Dr. Abelmann states that in all probability the next great maximum of the *Bielids* will occur on 1911 November 17, while a lesser display may be looked for on November 17 in either 1904 or 1905. This is, however, based on the supposition that two periods of the shower equal thirteen years. The active return of the shower in 1892 indicates a somewhat longer period, and this is confirmed by the failure of the meteors to appear in 1898. There were, it is true, fine displays in 1872 and 1885, but it is highly probable that the Earth passed through a section of the stream in the rear of the comet in the former year, while in the latter it passed

in front of it. The conditions appear to the writer to predicate a brilliant display in 1905.

Meteoric Showers observed in 1898.—Professor A. S. Herschel, at Slough, registered the paths of 68 meteors seen on clear nights between April 12 and 24, but there were very few, if any, *Lyrids* amongst them, though they gave ample evidence of minor showers in *Corvus*, *Libra*, *Ursa Major*, *Draco*, and the region of *Hercules*. Mr. W. E. Besley, of Westminster, during a watch of 3½ hours on April 21 and 22 recorded 20 meteors, of which 12 were *Lyrids*, with radiant at 273°+33°. The *Perseids* were well seen, and especially so on August 11, which furnished a night of exceptional clearness. A single observer, watching the sky uninterruptedly, might have counted about 50 meteors per hour, and of these about 40 would have been *Perseids*. The entire duration of the shower was included within the dates July 14 to August 17, but it furnished few meteors near the beginning and end of the period named. Some details of the observations are given in *Knowledge*, 1898 September and October.

Leonids.—Many preparations were made to observe the *Leonids* at the middle of November, but cloudy weather frustrated nearly every attempt in this country. A few detached observations during brief intervals of clear sky were obtained at several places, but the results were meagre and comparatively few meteors were noticed. The results, however, such as they were, sufficiently proved that, making due allowance for the bad weather, the *Leonids* could not have returned in the strength expected, but must have formed a comparatively weak display. Reports from America were more favourable, for the weather proved clear at many places on the morning of November 15, and a fair number, if not a rich display, of meteors were observed. At Princeton Professor Young, observing with Professor Reed, between $3^h\ 15^m$ and 5^h A.M. of the date mentioned, counted about 100 meteors, and estimated that the maximum occurred at about 3.45 A.M. (=G.M.T. 8.45 A.M.), when for 20 minutes meteors appeared at the rate of 2 or 3 per minute. At Harvard College Observatory Professor Pickering and his assistants counted an aggregate of 800 meteors, and secured 31 trails of 8 different meteors by photography. Four of these were photographed at two different stations, and will be available for determining the real paths with great accuracy. A preliminary determination of the radiant was made by extending back four of the trails. These converged sharply upon a focus, the greatest deviation being only 10′, and the radiant point came out at R.A. $10^h\ 6^m{\cdot}8$, Decl. 22° 16′ (1900). The maximum of the shower occurred at 3 A.M. (G.M.T. 8^h), when 61 meteors were counted east of the meridian in 30 minutes. Professor Pickering remarks that the photographic results prove that meteoric showers may now be studied to advantage by photography. At the Yerkes Observatory Professor Barnard watched the sky between midnight and sunrise on November 15, and counted several hundreds of meteors, many of which were of

the first magnitude and a few brighter. The maximum seemed to be reached between 3 and 4 A.M. (corresponding to 10 A.M. G.M.T.), perhaps nearer 4 A.M. On the mornings of November 16 and 17 not a single *Leonid* was seen. At the Lick Observatory Mr. C. D. Perrine watched for a certain interval on each of the nights from November 11 to 16, the weather conditions being good. Few meteors were witnessed, except on the morning of the 15th, between 2.24 and 4 A.M., when 73 were counted, the average number per hour being 44. He describes the *Leonids* as having "strong trains, rather slow motion, and bluish or greenish-white colour." The radiant was diffuse, for the path-directions of such meteors as were charted seemed to have come from almost all parts of the "Sickle." One fine *Leonid* was seen at $13^h\ 46^m\ 44^s$ P.S.T. It was estimated thirty or forty times as bright as *Venus*, and it left a cloud of *débris* which remained visible 42 minutes. At Northfield, Minn., Professor Payne counted 81 meteors (nearly all *Leonids*) between $0^h\ 30^m$ and $3^h\ 45^m$ A.M. November 15. Professor Wilson, observing at the same place, remarks that, owing to the fact that very few meteors were seen within 10° of the radiant, the photographs were disappointing. Two trails were, however, found upon the plates, and the former were perfectly straight, intersecting at R.A. $10^h\ 6^m$, Decl. 22° 18′. This is practically identical with the photographic radiant derived at Harvard, and suggests that we have now obtained a very accurate value for this position. At Philadelphia Mr. H. R. Smith made observations on the same morning between $0^h\ 20^m$ and $4^h\ 30^m$ A.M., and counted 76 meteors. At Carlisle, Pa., Professor Landis, with several other observers, estimated the average hourly number as from 100 to 125. Mr. Brackett made observations at Claremont, Cal., assisted by a small class in astronomy, at Pomona College. On morning of November 14, 134 meteors were seen from 0.45 to 3.45 A.M.; while on following morning, in four hours, 172 were seen. The maximum occurred at 2.27 A.M. P.S.T. November 15, when 12 were seen in 3 seconds. Mr. Easton, at the University of Iowa, assisted by eight students, counted 913 meteors between $0^h\ 20^m$ and $5^h\ 45^m$ A.M. November 15, Central time, and found two well-defined maxima at $2^h\ 10^m$ and $3^h\ 50^m$. At Colombia, Mo., Professor Updegraff counted 50 meteors in 88 minutes. Professor Wilson, in discussing the various observations, is led to conclude that the average hourly number of *Leonids* to be seen by one observer on the morning of the 15th was about 40. At Rome observations were favoured by fine weather. At the Observatory, on the night following November 13, during five hours 159 meteors were seen. On November 14, during 2½ hours after midnight, 126 meteors were seen, and of these 36 were of the first magnitude and a similar number of the second magnitude. Many other reports come from different quarters, and they prove that, compared with the *Leonid* displays of 1895, 1896, and 1897, the shower of 1898 showed a considerable increase in intensity.

It was not brilliantly manifested anywhere, but it was sufficiently pronounced and striking to give an earnest of the great accession of strength it will certainly receive by the time of its next return.

One notable feature in connection with the shower of *Leonids* in recent years is that the American observations place the radiant about 2° S. of the mean position determined from a large number of observations extending over the last 65 years. The writer found this mean position to lie at α 149° 28′, δ + 22° 52′* from 70 radiants. Professor W. H. Pickering from observations in 1897, and Professor Wilson from observations in 1898 (*Popular Astronomy*, 1898 December, p. 578), place the radiant a little further south, and it may be interesting to compare these results with a number of observations made in England during the last three years.

Leonid Radiant Point.

American Observations.†				English Observations.			
Observer.	Date.	Meteors.	Radiant.	Observer.	Date.	Meteors.	Radiant.
Davis	1898. Nov. 14	9	151°·0 + 22°·0	Besley	1897. Nov. 13–15	21	149°·0 + 23°·0
Smith	14	12	150·0 + 20·0	Herschel	1896. Nov. 14	34	148·5 + 23·5
Culbertson	14	30	149·6 + 22·2	Corder	12–13	20	146·0 + 25·0
Payne	14	[illegible]	148·0 + 20·5	Corder	14	43	150·0 + 23·0
Payne	14	19	149·6 + 20·9	Denning	14	11	150·0 + 22·5
Wilson	14	16	149·6 + 21·5	Milligan	14	9	149·0 + 23·0
Wetherbee	14	12	149·5 + 20·9	Besley	14	7	149·0 + 22·0
Parkhurst	14	3	150·0 + 20·2	Backhouse	14	17	152·0 + 22·0
Young	14	100	151·0 + 22·5	Backhouse	13	8	150·0 + 24·0
Wendell	1897. Nov. 13	[illegible]	149·7 + 21·7	Blakeley	13	12	150·0 + 25·0
Pickering	13	5	147·5 + 21·5	Herschel	1895. Nov. 12–14	9	151·0 + 23·0
Swasey	1895. Nov.		146·3 + 22·0	Corder	12–17	36	152·0 + 23·0
				Booth	13	11	154·0 + 24·0
				Blakeley	12–17	17	150·0 + 23·5
Mean of 12			149·3 + 21·3	Mean of 14			150·0 + 23·3

The difference is much larger than would have been thought probable, and shows the necessity of a more accurate method such as photography. By the latter method Professors Pickering and Wilson place the declination of the radiant at 22°·3, which falls exactly between the English and American observations. The

* This position, however, requires a slight increase in R.A., for many of the observers employed out-of-date globes or maps in obtaining it.

† We are indebted for many of these particulars to *Popular Astronomy* for 1898 December and 1899 January.

mean of the writer's own visual observations (1876–1896) of this centre (corrected for precession and brought up to 1900) is $150^\circ{\cdot}1 + 22^\circ{\cdot}0$.

According to several of the observers the maximum occurred between 8 and 10 A.M. G.M.T. November 15. The most probable time of greatest frequency from an average of the various estimates is indicated at about 8·30 A.M., but it seems to have varied at different places.

Several of the observers of the recent shower agree that *Leonids* were very rare on the morning of November 16. This is surprising when we remember that, in consequence of the perturbations experienced in late years, the meteors ought to have arrived late and displayed themselves most numerously at the very time when the shower was practically exhausted. This circumstance shows that considerable uncertainty must still prevail as to the precise time when the maximum is likely to occur in 1899.

The Meteoric Shower of Biela's Comet.—Moonlight and very unfavourable weather prevented a successful watch for this display. But it is certain that the shower did not return except possibly in a very feeble character. Usually it endures actively for several nights, but the meteors seemed quite absent on clear nights near the important date of November 23. It is highly probable that in November last the Earth traversed a section of the meteoric orbit far in advance of the cometary nucleus where few, if any, of the meteoric particles have been distributed.

The Geminids were seen under favourable circumstances, the sky being clear and the Moon absent. Between $9^h\,5^m$ and $10^h\,5^m$, December 12, Mr. Nielsen, at Hartlepool Cliff, counted 35 *Geminids*. Many were also seen by Mr. King at Leicester, and Mr. Besley at Westminster.

Fireballs.—Several brilliant fireballs were observed during the year and their real paths have been very satisfactorily computed. Details of the results have been published in the *Observatory* for 1898 October, and in various numbers of *Knowledge*. On January 21, $5^h\,32^m$, a brilliant *Cancrid* (radiant $130^\circ + 30^\circ$) fell from heights of 82 to 25 miles over the S. of England and the English Channel. On February 20, $8^h\,54\frac{1}{2}^m$, a fine *β Leonid* (radiant $176^\circ + 12^\circ$) was seen over the English Channel descending from 61 to 27 miles. On April 5, $10^h\,15^m$, a large meteor from *Monoceros* (radiant $121^\circ - 1^\circ$) was also well observed traversing a tolerably long flight of 162 miles with a velocity of only 11 miles per second. The observed heights were from 89 miles over the English Channel to 25 miles above Bisley. On July 26, $9^h\,10^m$, a *Capricornid* (radiant $269^\circ - 23^\circ$), estimated to be half as bright as the full Moon, passed slowly from over the coast of France to Cambridgeshire, falling from 73 to 27 miles above the Earth's surface. On August 11, in the twilight at $8^h\,58^m$, a very bright *Aquarid* (radiant $339^\circ - 10^\circ$) was seen by many observers. It travelled along a path of 196 miles from the mouth of the Seine, France, to Okehampton, and varied in height from 66 to

41 miles. On August 21, 9^h 16^m, an unusually large *Pegasid* (radiant $5°+13°$) attracted attention. It descended from 60 miles over Cressy in France to 29 miles over the English Channel.

W. F. D.

Sun-spots and Faculæ during 1898.

The usual note on Sun-spots and faculæ for the year 1898 has been to a large extent anticipated this year by a paper in the number of last November.

The year 1898 had, up to the end of August, showed a marked decrease as compared with 1897 in Sun-spots. The number of days on which the Sun was free from spots had already passed the total of such days for the whole of 1897, and in spite of outbursts in March and at the beginning of August the average spotted area was only 60 per cent. of that for 1897. During September, however, an enormous spot group made its appearance, its mean daily area approaching to one six hundredth part of the visible hemisphere. At the end of the month it made its second appearance, and at the end of October it appeared a third time, only, however, to quickly fade away. It was accompanied by considerable activity on other parts of the Sun's surface. The outburst seems to have spent itself by the middle of November.

The average spotted area for the whole year may be estimated at about 420 millionths of the visible hemisphere, a fall of 20 per cent. as compared with 514 for 1897. The predominance remains as before with the southern hemisphere, and there has been no marked change in the mean latitude or distance from the equator, none at any rate that forces itself upon notice before exact figures are available. The thirty odd days without spots during the first eight months of the year will probably be found largely supplemented during December.

P. H. C.

Total Solar Eclipses.

1898 *January* 22.

The almost universal disappointment that met those who journeyed to observe the eclipse of 1896 was amply compensated for in the past year. The eclipse of 1898 January, whose track lay over easily accessible parts of India, attracted a large number of observers, and, owing to the exceptionally favourable weather conditions which prevailed, results of the utmost value and importance were obtained.

None of the observers have as yet published any full report on their work, and only in a few cases have short preliminary accounts appeared, so that it is obviously impossible to speak with any confidence as to the final outcome of the observations made. We may, however, allude briefly to a few of the more salient points.

Four stations were occupied by observers sent out by the Joint Permanent Eclipse Committee, as follows:—

(1). At Sahdol. Mr. Christie and Professor Turner. The work undertaken by the former was the photography of the corona on a large scale, four inches to the Moon's diameter, with the Thompson photoheliograph, the same instrument which it had been intended to use in Japan in 1896. The photographs secured are of unusual excellence, and exhibit the delicate coronal structure with extreme fidelity. Mr. Christie is of opinion that his photographs show a connection between the prominences and the coronal streamers.

One point which it was specially desired to test was as to the relative advantages of direct images with long focus lenses as compared with the use of a secondary enlarging lens for obtaining large scale views.

The photographs obtained by Mr. Christie show that the enlarged image is certainly not inferior to the direct one, so that when we consider the great difficulty of mounting a very long telescope for eclipse work, it would seem that the enlarging lens is likely to be used exclusively in the future.

Mr. Christie also obtained photographs of the partial phase before and after totality, for determination of the position of the Moon relative to the Sun.

Professor Turner took a series of photographs with the "double tube" camera, and also with a polariscopic camera. The latter instrument showed very definite traces of polarization in the corona, and the photographs, when measured, should yield interesting results.

(2). At Goglee Dr. Copeland took a series of photographs with a long focus camera fixed in a horizontal position, and also with a small quartz prismatic camera and a slit spectroscope.

(3). At Pulgaon Captain Hills and Mr. Newall were stationed. A good series of corona pictures with the second "double-tube" camera, the duplicate of the one used by Professor Turner, was secured at this station.

Mr. Newall used a spectroscope with two slits, with which it was hoped to get photographs for the determination of the motion in the line of sight of the two portions of the corona situated on opposite sides of the Sun. Owing to the rapid falling off of the coronal light on receding from the limb, this observation was not successful, but a good photograph of the spectrum of the lower chromosphere was secured with the instrument.

Captain Hills used two large slit spectroscopes for recording the spectrum of the corona and of the solar chromosphere at moments of second and third contact. A good series of photographs was obtained, which show the whole history of the spectrum of the limb at the moment of contact. The corona spectrum shows several strong, bright lines of undoubtedly coronal origin.

(4). At Viziadrug on the west coast were Sir N. Lockyer and

party assisted by the officers and men of H.M.S. *Melpomene*. The programme undertaken was an extensive one, embracing visual and photographic observations of the corona, and a spectroscopic attack on the chromosphere with two large prismatic cameras. The series of photographs obtained with the latter instruments are of great value, and when fully examined and discussed should throw much light on the constitution of the lower regions of the solar atmosphere. One interesting point, which has already arisen, is that Sir N. Lockyer has pointed out that the strong coronal spectrum line in the green is by no means coincident with the chromosphere line at 1474 K. This is a point to which observers have apparently directed no special attention, having been content to accept on faith the original statement of Professor Young, to the effect that the green corona line was coincident with 1474 K.

In addition to these parties, there were a large number of other observers.

Professor Michie Smith, of the Madras Observatory, who was at Sahdol, took some very successful large-scale photographs with a long focus lens.

Professor Campbell, of the Lick Observatory, who was stationed near Jeur, carried out an extensive programme, including large-scale views of the corona and much spectroscopic work.

In this neighbourhood was also Mr. Burckhalter, who for the first time employed successfully his device for equalising the exposures to the inner and outer portions of the corona by means of a rotating sector.

The rapid diminution of the coronal light on receding from the limb, before alluded to, militated against the complete success of the experiment, though the actual photographs are described by those who have seen them as of unusual beauty and delicacy.

Prof. Naegamvala of the Poona College, assisted by a number of his students, secured an excellent series of photographs both of the corona and also of the chromosphere spectrum with the prismatic camera.

A large number of observers connected with the British Astronomical Association were distributed at various places along the line of totality, and in many cases secured results of great interest and importance. In particular we may mention the magnificent spectrum photographs taken by Mr. Evershed at Talni. These were done with a prismatic camera, and are remarkable for the great extent of ultra-violet spectrum shown. Mr. and Mrs. Maunder were also at this place, and were fortunate enough to obtain a corona photograph on a small scale, showing a very long extension of one of the streamers.

A Japanese party, under Mr. Hirayama, of the Tokio Observatory, was stationed near the coast, but, beyond a general report that their observations were successful, no details have as yet come to hand.

The most northerly station occupied was Dumraon, where Mr. Pope, of the Indian Survey Department, used a small camera with a Dallmeyer lens of 3-feet focal length.

To summarise the results, we may say that this eclipse will be chiefly memorable for the variety and excellence of the photographs secured of the spectrum of the lower chromosphere, the so-called "flash" spectrum, visible only at the moments of second and third contact.

The question of the relation between this and the ordinary solar spectrum may be considered as settled. It is now quite evident that this "flash" spectrum is not simply a reversed Fraunhofer spectrum, but has a quite definite character of its own. The identity of the spectra at second and third contacts, *i.e.* at opposite limbs of the Sun, shows clearly that the photographs obtained are spectra of the true chromosphere, and are not due to any local conditions such as the presence of a metallic prominence.

This is also exhibited plainly by comparing them with the single photograph taken by Mr. Shackleton in 1896, which is identical in character, though containing much less detail, with those taken in India.

Sir N. Lockyer has pointed out that there is a close similarity between the chromosphere spectrum and that of the star γ *Cygni.*

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The preparations for the eclipse are already in progress, and the Joint Permanent Eclipse Committee hope to send out parties to occupy stations in Portugal, Spain, and Africa. The Committee will probably not send any observers to America, but they hope to be able to arrange for a set of photographs to be taken at the western end of the line of totality with one of the double-tube cameras.

E. H. H.

Poincaré's Mécanique Céleste.

The chief event of the year, so far as Dynamical Astronomy is concerned, has been the completion of M. Poincaré's *Méthodes Nouvelles de la Mécanique Céleste.* The first two volumes of this work and the first part of the third volume were reviewed in last year's report.

The latter half of the third volume is chiefly concerned with *periodic solutions of the second kind*, which were first considered in the author's memoir: "Sur le Problème des Trois Corps," in 1889. In the first volume of the present work the general theory of periodic solutions (*i.e.* solutions of the problem of three bodies, in which the relative movement repeats itself at regular intervals of time) was developed; it was there shown

that, in one important class of such solutions (*periodic solutions of the first kind*), the co-ordinates of the body describing the periodic orbit could be expanded in ascending integral powers of the parameter which represents the disturbing mass. There are, however, periodic solutions in which the co-ordinates cannot be so expressed, and which may be arrived at as follows: Consider a periodic solution of the first kind, and form the equations which determine small oscillations about this motion. It may happen that one of the periods of the oscillations is nearly commensurable with the period of the orbit. In this case, solutions exist which differ but little from the periodic solution of the first kind, and have a period which is a multiple of its period: these are the periodic solutions of the second kind.

M. Poincaré has connected these results with the theory of Least Action. In a note in *Comptes Rendus* (1896) he has shown that, when the law of force is the inverse nth power of the distance ($n > 2$), the existence of an infinite number of classes of periodic solutions of the problem of three bodies can be deduced from the principle of Least Action. In a further note (*Comptes Rendus*, 1897) he has distinguished two kinds of unstable periodic solutions, by the aid of Jacobi's theory of Kinetic Foci. In the present volume the methods thus introduced are considerably extended.

As an application of the theory thus developed, the author discusses the periodic orbits which have been traced by mechanical quadratures by Professor G. H. Darwin (*Acta Mathematica*, xxi.). Professor Darwin considers that case of the problem of three bodies, in which two of the bodies, S and J, revolve round each other in circular orbits, and the mass of the third body, P, is infinitely small. He finds that in this case there are six families of periodic orbits; in one (Planet A) the small body P describes a closed path round the body S; in two others (oscillating satellites a and b) P oscillates about a position on the line joining S and J; and in the remaining three (Satellites A, B, C) P describes a closed path round J.

When different values are assumed for the energy of the system, the orbits of these families change their form, pass from stability to instability and *vice versa*, and even go out of existence altogether. M. Poincaré finds that in all cases but one these changes are in accordance with his own results. He further shows that when the orbit of Planet A is on the point of changing from stability to instability, periodic solutions of the second kind exist, each in the form of a closed curve with a double point, making two circuits round S. The two loops of such an orbit are each nearly circular. Similarly, when the orbit of Satellite C is on the point of changing from stability to instability, periodic solutions of the second kind exist, which make double circuits round the body J.

The contradictory case mentioned above occurs in considering the change of the orbit of Satellite A from stability to

instability. The difficulty of reconciling Professor Darwin's results with his own leads M. Poincaré to believe that the unstable form of Satellite *A* is not the true continuation of the stable form.

The last chapter of the book deals with *doubly asymptotic solutions.* It has been shown in the first volume that, corresponding to an unstable periodic solution, a set of solutions exists which originally differed widely from the periodic solution, but which tend to coincide with it when the time t is very large and positive. Similarly, another set of solutions can be found, which originally differed but little from the periodic solution, but which differ widely from it as t increases. These are two classes of *asymptotic solutions*; a solution which belongs to both classes—*i.e.* is approximately periodic when $t=-\infty$ and $t=+\infty$, but is not periodic in the meantime—is said to be *doubly asymptotic.*

It is much to be hoped that a continuation of the work begun by Professor Darwin will before long furnish us with concrete examples of many more of the beautiful results of M. Poincaré's theory. E. T. W.

Dr. Hermann Struve's Researches on the Satellites of Saturn.

Preliminary accounts of the results of Dr. Struve's researches have been given by him in the *Astronomische Nachrichten*, and notices of these are contained in the Reports of the Council for the years 1890 and 1892. The complete discussion of the observations made by Dr. Struve with the 30-inch refractor of the Pulkova Observatory during the years 1886–1892 has been recently published in vol. xi. of the *Publications de l'Observatoire Central Nicolas* (St. Petersburg, 1898).

With the 15-inch refractor Dr. Struve had previously made a series of observations of *Titan*, *Iapetus*, *Dione*, and *Rhea*, with the special object of determining the mass of *Saturn*. In the series of observations with the 30-inch little attention has been given to *Iapetus*, but an extensive series of observations of the positions of the other satellites with reference to *Saturn* or to one another has been made, as the following table, giving the number of different nights on which observations of the various classes were made in the different years, shows :—

	Tethys—Rhea.	Enceladus—Tethys.	Dione—Rhea.	Mimas.	Rhea—Saturn.	Titan—Saturn.	Hyperion—Saturn.	Hyperion—Titan, &c.	Iapetus.	Position Angle of Line of Ansæ.
1886	39	28	...	1	...	...	...	...	3	...
1887	47	28	...	2	...	...	48	41	...	...
1888	36	30	28	5	...	...	24	32	3	...
1889	42	36	33	22	21	...	32	9	4	...
1890	43	36	39	37	23	...	12	21	6	...
1891	42	40	39	32	...	27	23	8	2	61
1892	32	28	31	16	...	30	22	6	8	38

From these observations are deduced the following numbers of determinations of the orbits of the satellites :—

Titan.	Rhea.	Dione.	Tethys.	Enceladus.	Mimas.	Hyperion.
2	14	5	14	7	5	6

These results, in conjunction with the earlier observations of Herschel, Lassell, Marth, Bond, Hall, Newcomb, are used to give the constants of *Saturn's* system, the elements of the orbits of the different satellites, the movements of the apses and nodes, the long inequalities, the masses, the position of the equator of *Saturn*, its mass and dynamical oblateness.

The measures were made with a position micrometer, and a power of 515 was used throughout. A red illumination of the field was found to show the satellites most clearly, and was constantly used, except in the case of *Hyperion*, where it was found necessary to use a dark field and bright wires. A complete measure consisted of eight measures of distance and eight of position-angle.

The following table is given exhibiting the probable error of a complete set of eight measures in the different series of observations :—

	Distance.	Position-Angle × Distance.
	″	″
Tethys—Rhea	±0·042	±0·041
Enceladus—Tethys	±0·047	±0·044
Mimas—	±0·062	±0·064
Hyperion—Titan	±0·084	±0·089
Hyperion—Saturn	±0·150	±0·123
Rhea—Saturn	{ ±0·060 ±0·049	...

In the measures of *Titan* and *Rhea* rectangular coordinates were obtained directly by moving the wire parallel to itself, so as to bisect the satellite and to touch the planet at the N. and S. or the E. and W. limbs in succession. The position angle of *Hyperion* was obtained by making the wire passing through it a tangent to the planet or to the ring successively in both positions, and subsequently applying a small correction to the mean. The measures of *Titan* and *Rhea* led to the curious result that the optical centre of the planet was about 0″·15 from its centre of gravity. This was traced to the effect of the different colours and appearance of the two poles of the planet, a fact which has been noted by other observers. The value of the screw was determined by a series of measures of A and Z in the cluster *h Persei*, stars whose relative positions have been carefully determined by the heliometric observations of Professor Schur, Dr. Elkin, and Dr. Peter.

With the wires perpendicular to the line joining the stars A and Z their distance apart was measured in one step and also

in three by taking two intermediate stars; and in this way a correction of $-0''.08$ to Struve's measures of distance was obtained, which was applied throughout the observations.

Most of the measures, as is seen from the table given above, are of the relative position of two satellites. From the measured distances and position-angles are found $x_1 - x_2$, $y_1 - y_2$, the differences of the rectangular coordinates of the two satellites parallel and perpendicular to the planet's equator. The values of x and y are obtained according to assumed elements, and the differences between the observed and computed values determined. Formulæ are obtained giving the corrections dx and dy in terms of corrections to the elements. These are equated to the quantities given above and equations of condition formed for the corrections of the assumed elements, which are solved by the methods of least squares. As an illustration of the accuracy of the results, the values obtained in the seven years 1886 to 1892 for the eccentricity of the orbit of *Enceladus*, whose mean distance is 34″, may be cited:—·00470, ·00385, ·00650, ·00354, ·00389, ·00421, ·00517.

From the discussion of these annual results the following values are obtained for the eccentricities and inclinations to *Saturn's* equator of the four inner satellites:

	Eccentricity.	Inclination.	Annual Movement of Nodes and Apses.
Mimas	·0190	1° 36′	365° 3
Enceladus	·0046	1	...
Tethys	·0000	1 4	72 5
Dione	·0020	4	30

Of these quantities the value obtained for the inclination of *Enceladus* is less than the probable error, and that for *Dione* is too near the probable error for much reliance to be placed on it.

The secular variation of the elements of these four satellites in mainly due to the oblateness of the planet, which causes a uniform progression of the apses and regression of the nodes. *Tethys*, *Dione*, and *Enceladus* give the position of the planet's equator, which is—

$$\text{Saturn's equator} \quad 1889{\cdot}25 \quad \Omega_1 = 167^\circ\ 57'{\cdot}0 \quad \iota_1 = 28^\circ\ 5'{\cdot}6.$$

In the case of *Rhea* the disturbing influence of the oblateness of *Saturn* is less, and that of the Sun and *Titan* is larger. For *Rhea* it is found that $e = 0{\cdot}0009$, and the annual progression of the apse and regression of the node is $10^\circ{\cdot}1$.

For *Titan* $e = 0{\cdot}02886$ for 1890, the movement of the apse is $31'{\cdot}7$ annually, and the plane of the orbit is given for the epoch $1890 + t$ by

$$\left.\begin{aligned} \Omega &= 167^\circ\ 51'{\cdot}2 + 35'{\cdot}84 \sin(47^\circ{\cdot}8 - 0^\circ{\cdot}506\,t) + 0^\circ{\cdot}837\,t \\ \iota &= 27^\circ\ 28'{\cdot}4 + 16'{\cdot}88 \cos(47^\circ{\cdot}8 - 0^\circ{\cdot}506\,t) \end{aligned}\right\}$$

To make the mean longitudes of the observations from 1831 to 1892 agree, an empirical term is added whose period is 50 years and amplitude 5′.

The motion of *Dione* and *Enceladus* shows an inequality whose argument is $2l_1 - l - \Pi$, where l_1 is the longitude of *Enceladus*, l of *Dione*, and Π the longitude of the apse. The period of this is about 12 years, and from it the mass of *Dione* is found to be $\frac{1}{536,000}$, and the mass of *Enceladus* to be only a small fraction of this.

A long inequality in the motion of *Tethys* and *Mimas* which produces a libration in longitude of nearly 45° in *Tethys*, and has a period of 70·6 years, is traced to the term whose argument is $4l_1 - 2l - \theta - \theta_1$, where θ and θ_1 are the nodes of *Mimas* and *Tethys* respectively on the planet's equator.

From this it is found that the inverse ratios of the masses of *Tethys* and *Mimas* to that of *Saturn* are respectively 907,600 and 13,610,000.

Combining these values with the equations for the masses derived from the observed motions of the apses or nodes, the inverse ratios of the masses of *Enceladus*, *Rhea*, and *Titan* to that of *Saturn* are found respectively to be :—

4,000,000, 250,000, 4,700.

It is further shown that the mass of the ring cannot be more than 1/26,720, and that it is probably much less than this. The constant of the disturbing function, due to the oblateness of *Saturn*, is determined, and by Clairaut's Theorem, using the period of rotation as given by Professor Hall, the ellipticity of the planet is deduced, viz. $\frac{a-b}{a} = 0·1031$. This value agrees with that obtained by Dr. Struve's measures, but is considerably larger than that obtained by Barnard and at Greenwich. As Dr. Struve has given in the *Monthly Notices*, vol. liv., an account of his measures,* and of his discussion of the observations of phenomena of the satellites, it is unnecessary to refer to them further.

The semi-axes of the six inner satellites are found to be :—

Mimas	″ 26·814
Enceladus	34·401
Tethys	42·586
Dione	54·543
Rhea	76·170
Titan	176·578

and the mass of *Saturn* is found $\frac{1}{3495·3}$.

* *On the Dimensions of Saturn's Disc*, by H. Struve.

As stated in the preface, only the more important features in the motion of *Hyperion* are considered in the discussion. The theory of this satellite is very difficult, on account of (i.) the magnitude of the ratio of the mean distances of *Titan* and *Hyperion* ($177'' : 214''$); (ii.) the commensurability of the mean motions ($4n' - 3n = \Delta\Pi'$) producing a large libration; and (iii.) the eccentricity of the orbit of *Titan*. If the libration be neglected and the orbit of *Titan* assumed circular, then the orbit of *Hyperion* is "periodic," and a method given by Dr. Hill (*A. J.*, No. 176) is taken as a basis of the discussion. The mean value of the semi-axis when *Hyperion* and *Titan* are in opposition is found to be $213''\cdot92$; the mean values (subject to large inequalities) of the eccentricity and annual motion of the apse are 0·1043 and $-18^\circ\cdot663$ respectively; the position of the plane of the orbit relatively to that of *Titan* for $1890+t$ is given by—

$$\sin i\,(\Omega - \Omega_{II}) = -0'\cdot6 + 2'\cdot7 \sin(47^\circ\cdot8 - 0^\circ\cdot50\,t) + 36'\cdot2 \sin(121^\circ\cdot7 - 2^\circ\cdot0\,t)$$
$$i - i_{II} = -7'\cdot6 + 2'\cdot7 \cos(47^\circ\cdot8 - 0^\circ\cdot50\,t) + 36'\cdot2 \cos(121^\circ\cdot7 - 2^\circ\cdot0\,t)$$

The period of the libration is $640^d\cdot5$, and its amplitude is $9^\circ\cdot16$. 'The rigorous representation of the observations must await a further development of the theory.'

The work concludes with a discussion of earlier observations, including those of Sir W. Herschel in 1789, of Sir John Herschel at the Cape in 1836, of Lassell from 1847–1857, of Bond at Harvard from 1848–1852, of Lassell and Marth at Malta 1852–1853, of Newcomb, Hall, and Holden at Washington from 1874–1879, and of Hall from 1882–1886.

No comment is necessary on the extent and accuracy of the observations, the thoroughness of the discussion, and the great value of these researches on *Saturn's* system. We may be permitted to express our admiration of Dr. Struve's lucid style, and of the excellence of the type and printing of this remarkable volume. F. W. D.

The Physical Aspect of the Planets.

There has been no remarkable advance in our knowledge under this head. Professor Schiaparelli has published his fifth memoir on *Mars*, increasing our knowledge of the surface markings and the changes therein. The true explanation of these changes, and of the duplication of the "canals" and the nature of the "seas," seems as far off as ever. The flooding of certain areas, and the thawing of the surface of lakes, seem to be the leading hypothesis. It seems that the duplication of canals begins one or two months after the vernal equinox, and is over by the summer solstice. Mr. Denning has examined the rotation period of *Jupiter*, as given by bright and dark spots in the region

of the equator, and furnishes a mean of $9^h\ 50^m\ 23^s{\cdot}6$ against $9^h\ 50^m\ 30^s$ previously adopted, showing an increase in rate from the spring of 1897 to the spring of 1898. The period of the great red spot from 17,414 rotations, according to Mr. Denning, comes out $9^h\ 55^m\ 39^s{\cdot}4$, but is not constant. The 413 rotations from 1880 Sept. 27 to 1881 March 17 gives $9^h\ 55^m\ 35^s{\cdot}6$, while 495 rotations from 1892 August 15 to 1893 March 8 give $9^h\ 55^m\ 42^s{\cdot}3$. Mr. Stanley Williams has investigated the motion of the South Temperate current, and finds a remarkable uniformity in its motion, which, so far as observations go, has not varied by more than 1·3 miles per hour from its mean value during the last 100 years.

G. M. S.

The Astrographic Chart.

As there has been no recent meeting of the Committee, with accompanying information from the Observatories, it is difficult to find data for a complete report of the progress of the work on the Astrographic Chart and Catalogue. The following figures, in some cases approximate, have been extracted from Reports of some Observatories; the dates to which they refer are given in the last column:—

	Zone.	No. of Plates Assigned.	Number Taken. Chart.	Catalogue.	Number of Plates Measured.	Number Reduced.	
Greenwich	$+90^\circ$ to $+65^\circ$	1149	923	971	394	232	1898 Dec. 31
Catania	+54 „ +47	1008	46	226	...	...	1897 Dec. 31
Potsdam	+39 „ +32	1232	...	781	149	149	1897 Dec. 31
Oxford	+31 „ +25	1180	none	600	500	466	1898 Dec. 31
Paris	+24 „ +18	1260	(not stated)	nearly all	about 440	about 110	
Cape	−41 „ −51	1512	about half	1512	27	...	
Melbourne	−65 „ −90	1149	278	1149	...	...	1898 June 30

At Catania 518 stars have been measured.

At Potsdam 63,000 stars have been measured, and the first volume of the Catalogue (20,000 stars) is ready for printing.

At Greenwich the measures of a zone, 4 degrees of declination wide, are ready for press.

Arrangements have been made between the Directors of the Sydney and Melbourne Observatories that the Catalogue plates taken at both institutions shall all be measured at Melbourne, the expense being shared by the Governments of New South Wales and Victoria. Mr. Baracchi, Director of the Melbourne Observatory having consulted the Astronomer Royal, has been furnished

with a complete description of the methods in use at Greenwich, and it is probable that the measuring and reduction of these southern zones will be shortly begun.

The most recent publications on this subject are Dr. Gill's description of the new measuring apparatus made by Messrs. Repsold for the Cape Observatory, and Professor Turner's note on this in the *Monthly Notices* for December and January. Professor Donner published a description of a micrometer for measuring astrographic plates, which Messrs. Repsold had made for Helsingfors Observatory, in *Öfversigt af Finska Vet. Soc. Förhandlingar*, B. xxxix. (1897 March).

H. P. H.

Star Catalogues.

Corrections to the Fundamental Catalogues of the Astronomische Gesellschaft.—In 1878 Dr. Auwers published a catalogue of 539 stars, extending from Pole to $-10°$ declination, for use in the Zone observations of the *Astronomische Gesellschaft.* This was supplemented shortly afterwards by 82 more stars extending from $-10°$ Decl. to $-30°$ Decl. The right ascensions and declinations in this catalogue are given for 1875·0. In 1888 Dr. Auwers published a second catalogue of 303 stars, extending from $-10°$ to $-30°$, and reduced to 1885·0. This catalogue contains 135 stars common to the previous catalogue. There is, however, a systematic difference in the declinations. In 1897 Dr. Auwers published a third fundamental catalogue of 482 stars, extending from $-23°$ to $-80°$, with a supplement of 24 stars between $-80°$ and the South pole. The two earlier catalogues were only intended to serve for the Zone observations, the proper motions of the stars given in them not being sufficiently well determined for the catalogue to be used over a long period of time. In the course of preparation of a new fundamental catalogue, which shall hold good for a larger time, Dr. Auwers has given in *Ast. Nach.* 3508–9 and in *Ast. Nach.* 3511 corrections to the right ascensions, declinations, and proper motions of the individual stars of these two catalogues, but has not as yet given the systematic corrections required by the catalogues. In the determination of these corrections the most recent observations have been used.

Astronomische Gesellschaft Catalogue. Kasan Zone.—The most northerly section of the catalogue of the *Astronomische Gesellschaft*, extending from 74° 40′ to 80° 20′ N. Decl., was undertaken by the Kasan Observatory. The observations were mostly made between 1869 and 1879, though supplementary observations were made from 1888 to 1892. The programme of the *Gesellschaft* (comprising all the stars down to the ninth magnitude in the *Bonn Durchmusterung*, and such fainter stars as have letters attached to them in that work, indicating that they have been previously observed), required the observation of 2,322 stars, but this

was largely extended, and 4,281 stars were observed. The average number of observations is 4·4 per star, and the probable error of a position is given as $\pm 0''\cdot 38$ in declination and slightly less in right ascension.

The Second Washington Catalogue of Stars.—This catalogue, as is stated in its preface, is made from all the observations made with the 8·5-inch transit circle of the Old Naval Observatory from its erection in 1866 till it was dismounted in 1891. The catalogue contains 5,151 stars, and is the result of nearly 73,000 observations. 43,000 of these observations were devoted to the stars of the *American Ephemeris*, but it was realised in 1875 that the observations were not sufficiently free from systematic error to be used for correcting the positions of the fundamental stars, and from that date attention was devoted entirely to the other stars, the stars of the *American Ephemeris* being only used for clock and instrumental errors.

Systematic corrections to the declinations are derived by comparison with the *American Ephemeris*, and as the 5,000 stars are well observed, seldom less than three times, their positions should be well determined.

F. W. D.

Double Stars.

The plan of this report follows that of previous years, the work being treated of under the two heads—"observation" and "calculation."

Observation.—The neglected southern hemisphere is now receiving more attention, and the best work of the year was in this region. The "Lowell" 24-inch refractor was placed at the disposal of Dr. See for the survey of the southern heavens for the discovery of new double stars and nebulæ. During a portion of 1896 and in 1897 Dr. See swept over the region included between $-20°$ and $-45°$ decl., and also a portion of the zone $-45°$ to $-65°$ decl., examining about 100,000 stars. The result is given in the "First Catalogue of New Double and Multiple Stars in the Southern Hemisphere," published in the *Astronomical Journal*, Nos. 431 and 432. This catalogue is composed of:

76	stars whose distance is between	$0''\cdot 0$	and	$0''\cdot 5$
46	" "	0·5	"	1·0
40	" "	1·0	"	2·0
338	" is over	2·0		

And as each of these stars has been measured at least two nights, it is a brilliant piece of work to have been performed in about one year.

Dr. See also made numerous measures of previous known doubles.

A.N. = *Astronomische Nachrichten.*
A.J. = *Astronomical Journal.*
M.N. = *Monthly Notices, R.A.S.*
Ast. Soc. Pac. = *Publication of the Astronomical Society of the Pacific.*

A.J. 439 contains measures of 23 selected pairs made by H. R. Morgan with the 26-inch McCormick in 1896. *A.J.* 447 contains a long series of measures made by Professor E. E. Barnard in 1892–4 with the 36-inch Lick refractor. These include OΣ 38, β 524, β 883, β 552, ζ *Herculis*, β 416, 99 *Herculis*, δ *Equulei*, κ *Pegasi*, and β 733.

A.N. 3518.—Dr. Knorre gives measures of 80 *Struve* and OΣ pairs made with a double-image micrometer on a 9·8-inch refractor.

M. Solá in *A.N.* 3497 and 3529 publishes measures of 62 pairs made at Girona with an 8½-inch refractor. The same observer gives in *A.N.* 3535 a triangulation of the cluster 6525 (M. 8).

A.N. 3501 contains the "Fifth List of New Doubles discovered at the Cape Observatory" (Nos. 260 to 305).

Observations of special stars are :

β 883.—*A.J.* 435, Barnard (Yerkes).
" *M.N.* May, See (Lowell).
Sirius.—*M.N.* April, Lewis (Greenwich).
" *M.N.* May, See (Lowell).
Procyon.—*A.J.* 435, Barnard (Yerkes).
" *M.N.* April, Lewis (Greenwich).
" *M.N.* May, See (Lowell).
Aldebaran.—From measures made by Mr. Aitken this year, and by Professor Burnham in 1891, with the Lick refractor, it is evident that the close star *B*, forming with *Aldebaran* the pair β 550, partakes of the proper motion of *Aldebaran*, while *C* and *D* form an independent system. These two systems are separating (*Ast. Soc. Pac.* No. 61).

Professor Belopolsky's researches on the relative motion, in the line of sight, of the components of γ *Leonis* and γ *Virginis* are in the *A.N.* 3510.

Calculation.—*A.J.* 400. Dr See, in a paper on "The System of *Procyon*," gives an interesting and comprehensive history of the work on *Procyon*, commencing with the suspicion of Bessel, that the irregularity observed in its motion was due to the fact that it was a real binary star, up to the time when in 1874 Dr. Auwers finally announced its binary character, and gave the period of revolution 39·972 years. During 1888 and 1890 Professor Burnham searched in vain for a companion with the 36-inch Lick refractor. It was really much closer than in 1896 when Schaeberle discovered it with the same instrument. Dr. See gives all measures up to 1898·2 and an ephemeris.

1899·20	334°·0 and 5″·00
1900·20	341°·0 „ 5″·26

His period is 40·0 years.

A.J. 434.—Mr. H. Norris Russell gives "a new graphical method of determining the elements of a double star orbit," founded on the use of the projection of the circle circumscribed about the true orbit, and is, therefore, practically the method previously given by Dr. Swiers in *A.N.* 3336—of which Mr. Russell was ignorant. He works out the orbit of η *Cassiopeiæ.*

M.N., May.—Mr. Burnham shows that the relative motion of γ *Leonis* is well represented by a straight line, and that it is impossible to derive an orbit.

M.N., June.—Dr. See has a paper on γ *Lupi*, for which pair he deduces an orbit with a period of 83 years. This is subject to revision, as the material employed is very slender.

A.N., 3525.—Dr. Doberck gives orbits for Σ 228 and OΣ 400, and is of opinion that the system of Castor revolves in an orbit considerably inclined to the plane of vision in a period between 90 and 150 years.

T. L.

Astronomical Spectroscopy.

The Spectrum of Nebulæ.—The question of the variability of the relative intensity of the bright lines in the spectrum of the nebulæ has been discussed with considerable activity in the past year. Keeler in 1894 (Lick Observatory 4to. Vol. III. p. 224) had pointed out the difference between the spectrum of hydrogen in the nebulæ and that of an ordinary hydrogen tube; whereas in nebulæ in general H_α is invisible, though H_β and H_γ are visible, in hydrogen tubes the H_α line is visible together with H_β, though H_γ is invisible. He has attempted without success to reverse the relative brightness of the lines H_α and H_γ by using increasingly powerful discharges, concluding that if this could be achieved with more powerful apparatus, the fact would point to an extremely high temperature or high degree of electrical excitement in the nebulæ. Scheiner (*Ast. Nach.* Bd. 145, p. 305), considering that the radiation of the nebulæ is from very attenuated gases in enormously thick strata, and at an external temperature which can differ but little from the absolute zero, has studied the spectrum of attenuated hydrogen at a temperature of about −200° C., and finds no change in the spectrum. He further points out that the invisibility of H_α in nebulæ is referable to the physiological cause which produces the Purkinje phenomenon, and which Abney's researches have made us familiar with—viz., two objects emitting light of different colours do not maintain the same apparent relation of intensities when their real intensities are altered in equal proportions. Scheiner

finds that at least an eightfold weakening of the light is required to make H_β disappear after H_α has vanished, and the requisite weakening may be as much as thirtyfold. Runge completes the history by showing that the Purkinje effect is 600 times as strong with the red and blue lines H_α and H_β as with the green and blue lines 5007 and H_β (*Astroph. Jour.* 1898, vol. viii. p. 32); and whilst agreeing with Scheiner in his view that the apparent invisibility of H_α in nebulæ is due to physiological causes, he points out that Campbell's observations, which Runge himself has corroborated whilst on a visit to the Lick Observatory (*Ast. Nach.* Bd. 145, p. 227), cannot be explained on this ground. Finally, Keeler describes further observations (*Ast. Nach.* Bd. 148, p. 207), which entirely confirm those of Campbell and Runge, and make it clear that there exist real differences in the relative intensity of the bright lines in different parts of the *Orion* nebula.

Velocity in the Line of Sight.—Campbell gives an interesting description (*Astroph. Jour.* 1898, vol. viii. p. 123) of the new spectroscope of the Lick Observatory, and of his method of measurement and reduction of the photographs of stellar spectra. A train of three dense flint prisms is used, of such size as to transmit a circular beam of H_γ light about $1\frac{1}{3}$ inches in diameter. The paper contains details of the reduction of a photograph of the spectrum of *α Tauri*, in which twenty-eight lines are used for the determination of velocity in the line of sight. A list of velocities for eleven stars is appended, in order that the nature of the results may be illustrated. From this list it is seen that Campbell's results for a given star on different nights are very consistent, and in many cases differ considerably from the results obtained at Potsdam. For instance, Campbell deduces a velocity of +0·3 km/sec for *β Andromedæ*, whilst the Potsdam result for the same star is +11·2, determined eight or nine years previously. Six photographs of *α Tauri* yield extremely consistent results, within a range of +54·3 and +55·7, with a mean +54·8, to be compared with +48·5 at Potsdam. Campbell calls attention to the variable velocity of *η Pegasi*; and the observations of Belopolsky (*Ast. Nach.* Bd. 148, p. 127) confirm his determinations, which point to the probability that the period of variation is a long one—possibly of the order of two or three years.

Parallax from Spectroscopic Observations.—Belopolsky (*Ast. Nach.* Bd. 147, p. 90) has attempted to deduce from spectroscopic determination of the velocities of the components of *γ Virginis* and also of *γ Leonis* the absolute dimensions and the parallax of these double-star systems. The results are to be regarded only as an experiment in an investigation which at the present time seems to be hardly within the instrumental powers at the disposal of observers. It is interesting, however, to record this attempt to carry out the suggestion originally made by C. Niven in 1874 (*Monthly Notices*, vol. xxxiv. p. 339).

Photographic Survey of Stellar Spectra.—It has been an-

nounced on an earlier page that the Council have awarded the Society's Gold Medal to Mr. McClean for his photographic survey of the spectra of the brighter stars in both hemispheres. The results of the survey which Mr. McClean has so admirably carried out are published in two parts: those relating to the northern hemisphere in the *Phil. Trans. of the R. S.* vol. cxci. (1898), and those relating to the southern hemisphere in *Spectra of Southern Stars* (Stanford, London, 1898).

The Echelon Spectroscope.—Professor Michelson has described (*Astroph. Jour.* 1898, viii. p. 37) a remarkable development of the diffraction grating spectroscope, which may possibly suggest a new departure in stellar spectroscopy. The resolving power of a grating is proportional to the product of n, the total number of lines ruled in the grating, and m, the order of the spectrum used. Ordinarily the effort has been made to rule a large number of lines and to use a low order of spectrum. For instance, many of Rowland's superb gratings have as many as 40,000 lines, and the spectra of the 3rd and 4th order may be advantageously used. Professor Michelson has designed a new form of grating with what is the equivalent of 20 rulings, and it appears that he uses spectra of about the 15,000th or 20,000th order. He is using the instrument in the investigation of the Zeeman effect, a research in which a very high dispersion and resolving power are desirable. The use of such high orders of spectra is only possible when the problem of concentrating the light in a single spectrum has been solved.

Printing of Maps and Tables of Spectra.—In 1896 the Editorial Board of the *Astrophysical Journal* announced that they intended as far as possible to adopt (i) Rowland's wave lengths, (2) the printing of spectra with red to right, (3) the printing of tables of wave lengths with short waves at the top, (4) the kilometer per second as the unit of velocity in the line of sight in astrophysical work. The difficulty of consistently adhering to rules of this kind is well exemplified by the fact that the first map of a spectrum published in the journal after this announcement was made was printed with the red to left. The Board, finding that many spectroscopists did not favour their resolutions entirely, invited further explicit opinions. It then appeared that there was general agreement as to the desirability of printing maps in the manner adopted by Rowland for his solar spectrum, red to right; but there was a strong feeling against printing tables of wave lengths with the short waves at the top. The Board of Editors, however, feeling, doubtless, that there was no immediate prospect of complete agreement, have decided to adhere to their practice of printing spectra red to right and tables short waves at top, except in cases where a wish to the contrary is expressed by the author of any contributed paper. (*Astroph. Jour.* vi. p. 353, 1897 November.) H. F. N.

Lunar Photography.

The modern era of lunar photography commenced with the erection of the Lick 36-inch telescope, which gives an unenlarged image about 6 inches in diameter. Some of the results are now rendered accessible in the *Lick Observatory Atlas of the Moon*, and in the Atlas published by Dr. L. Weinek, which consists of enlargements from Lick and Paris negatives. The scale adopted by Dr. Weinek for the Lick photographs is an enlargement of 24 diameters, giving a lunar diameter of 10 feet; but it is not stated which of these numbers varies with the apparent diameter. The factor for the Paris plates is given as 23·39, and the resulting diameter 4 metres. The sheets are of a convenient size (17½ inches by 13 inches) well adapted for studying individual formations, but necessarily small for more extended areas. Four parts, each containing twenty plates, have already appeared. The scale adopted brings out all the detail which can be reproduced from the original negative, but it also shows the grain with a prominence which impairs the general effect. This is avoided in the *Lick Observatory Atlas*, the scale of which is three Paris feet, 38·36 inches, to the Moon's diameter. This gives admirable pictures, in which the light and shade are well preserved and the detail clearly brought out; but the reproductions being by the collotype process, slight differences of tint must be interpreted with caution, a comparison of different copies of the same plate shows that they do not always agree in this respect. The sheets are not too large (20 inches by 16 inches) for handling, yet large enough to show general features; it is much to be regretted that this Atlas, which would meet a recognised want, is not to be obtained by purchase. Nineteen plates have been issued.

A third Atlas is being published by MM. Loewy and Puiseux from negatives taken with the equatorial *coudé* of the Paris Observatory. The diameter of the image at the principal focus may be nearly seven inches, and the scale of enlargement corresponds to a lunar diameter varying between 1·26 and 2·72 metres. This plan has been adopted after due consideration, the scale for each plate depending partly on the magnification the negative would bear, partly on the character of the objects, it being desirable in some cases to show a considerable region, in others to bring out as much detail as possible. In taking the photographs the telescope has been fixed, the plate receiving a rectilinear motion from a specially contrived mechanism. Seventeen enlarged heliogravures have been published, with three exquisite prints identical in size with the original negatives. The plates are very large (31½ inches by 23½ inches), in order to show the connection between the general features over a large area.

The plates are accompanied by a detailed discussion of their bearing upon the problems of selenography. That the Moon is not completely covered with ice is shown by the absence of a

directly reflected image of the Sun, and of sheets of water formed under its action, confirming the conclusions from the angle of polarisation obtained by M. Landerer. If there were polar caps the lines of demarcation should be apparent, and the smaller crevices in the polar regions should be filled up; but, in the neighbourhood of the south pole especially, these are more marked than in the equatorial regions. It is considered uncertain whether there may not be small quantities still contained at the bottom of some of the ring plains. The changes of colour seen near the terminator, and differences of tint shown by photographs taken at various phases, support the belief that this may be so. The absence of converging river valleys, and of any conspicuous signs of erosion, indicates that the water originally on the Moon percolated at an early period, and was absorbed by the rocks of the interior.

MM. Loewy and Puiseux divide lunar history into five periods gradually merging into one another. When solidification was commencing, currents, caused by tides and differences of temperature, induced alignments of floating solid material, whilst causing channels to be kept open in other directions. The crust forming more thickly about the floating masses produced lines of greater strength which have frequently determined the polygonal outlines of the subsequently formed walled plains. After the crust was formed fissures appeared, and when the opposite edges were brought together under horizontal pressure similar lines were formed having great power of resistance. When the edges were separated valleys resulted. In the second period the lava accumulating under the attraction of the Earth, or from some other cause, formed openings in the crust, through which it flowed, producing mountain chains of which the Apennines are the most important vestige. In the third period conical hills arose, the central parts of which sank in successive stages as the interior pressure diminished, leaving the concentric terraces seen in the older ring plains. Where central cones remain these indicate volcanic orifices near the original summit. In the fourth period contraction of the interior fluid caused large regions of the surface to sink, producing the seas, and lava flowing through the lines of fracture submerged the existing formations. These subsidences occurred mainly in the equatorial regions, because motion of the lava was there still maintained by tidal action. The formations about the south pole are held to be the most ancient; the difference between this region and that about the north pole supports Professor Darwin's view that the axis of rotation has undergone considerable displacement. If we could see round the north limb we should probably find a region resembling that about the south pole. In the fifth period, perhaps not yet concluded, local eruptions created parasitic orifices in the mountainous regions, whilst the greater homogeneity of the crust over the seas caused the production of regular cones, transformed into ring plains by subsidence of the central parts. These

recent foundations, of which Copernicus is typical, are characterised by regularity of form, isolated situation, and white borders. The light radiating streaks are the latest manifestation of volcanic energy, and are attributed to cinders or dust, carried by currents of air and deposited on the surface. They afford evidence of the previous existence of a denser atmosphere than the Moon now possesses. These cinders were to a less extent distributed over the surface, except where the dark spots mark what were then small lakes. The greater brightness at the poles, and round the limb generally, is due to the fact that these parts receiving less of the heat radiated from the Earth, and being less disturbed by the tides, were the first to solidify, and have experienced fewer surface changes; they have, therefore, a denser deposit of cinders.

Whilst the photographs give invaluable records of the bolder features, the more minute details are obliterated by atmospheric disturbances during the period of exposure, and can at present only be reached by visual observation. Herr Krieger has commenced the publication, under the title of *Mond Atlas*, of a series of sketches of various formations in which he strives to fill in what is lacking in the photographs. These show often a considerable amount of detail, though only such as could be seen in the particular state of illumination and libration under which each was made, and the shadows are in many cases conventional.

The fourth Report of the Lunar Section of the British Astronomical Association contains a summary of observations made upon a few selected formations. These have resulted in the discovery of many minute details not previously recorded, and in the rediscovery of some objects which have for a time been considered as missing, affording another illustration of the great caution necessary before admitting the reality of supposed physical changes.

S. A. S.

Papers read before the Society from March 1898 to January 1899.

1898.

Mar. 11 The Wilsonian theory and Mr. Howlett's drawings of Sun-spots. Rev. A. L. Cortie.

List No. 6 of nebulæ discovered at the Lowe Observatory, Echo Mountain, California. Lewis Swift.

The concave grating for stellar spectroscopy. C. L. Poor.

On a convenient method of adjusting a polar axis to the diurnal motion. D. P. Todd.

Nebulæ discovered at the Royal Observatory, Cape of Good Hope. Communicated by H.M. Astronomer.

List No. 7 of nebulæ discovered at the Lowe Observatory, Echo Mountain, California. Lewis Swift.

Long-enduring spots on *Jupiter*. A. Stanley Williams.

Notes on the rotation period of *Venus*. E. M. Antoniadi.

Equatorial Comparisons of *Neptune* with 114 (*o*) *Tauri*, 1897 December. John Tebbutt.

A remarkable object in *Perseus*. Rev. T. E. Espin.

On the "two method" personal equation. W. W. Bryant.

The spectrum of *o Ceti*, as photographed at Stonyhurst College Observatory. Rev. W. Sidgreaves.

The effect of latitude variation on the ecliptic investigation. W. G. Thackeray.

Mean areas and heliographic latitudes of Sun-spots in the year 1896, deduced from photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius. Communicated by the Astronomer Royal.

Ephemeris for physical observations of the Moon, 1898 April 16 to 1899 January 1. A. C. D. Crommelin.

Note on Dr. Gill's paper on the effect of chromatic dispersion of the atmosphere on the parallaxes of *α Centauri* and *β Orionis*. A. A. Rambaut.

Note on the Zodiacal Light. E. W. Maunder.

April 6. List No. 8 of nebulæ discovered at the Lowe Observatory, Echo Mountain, California. Lewis Swift.

Note on some results obtained with a small prismatic camera at the eclipse camp at Talni. John Evershed.

Observations of nebulæ. H. A. Howe.

A revolver eye-piece electrically warmed. A. F. Lindemann.

Second attempt to photograph the *Leonid* meteor swarm. Isaac Roberts.

Comparison of the forthcoming Greenwich Ten-year Catalogue for 1890 with certain Fundamental Catalogues. Communicated by the Astronomer Royal.

Observations of the companions of *Sirius* and *Procyon*, made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Times of transits of the zero meridians of the two adopted systems across the centre of the illuminated disc of *Jupiter*. A. C. D. Crommelin.

May 13. Elongations of *Jupiter's* fifth satellite, 1898 April 10 to June 19. A. C. D. Crommelin.

Note on the Zodiacal Light. William Anderson.

Micrometrical measures of the double stars β 883, *Sirius*, and *Procyon*. T. J. J. See.

The relative motion of the components of γ *Leonis*. S. W. Burnham.

Vanadium in the spectrum (C to D) of Sun-spots. Rev. A. L. Cortie.

A determination of the proper motions of the Greenwich clock stars from Greenwich transit-circle observations, 1854–96. W. G. Thackeray.

Observations of Comet *b* 1898 (*Perrine*) made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

The markings of *Venus*. A. E. Douglass.

Photographs of the nebulæ in the *Pleiades*, of stars in the surrounding regions, and of spurious nebulosity. Isaac Roberts.

June 10. Observations of the phenomena of *Jupiter's* satellites with the 8-inch equatorial of the Windsor Observatory, New South Wales, in the year 1897. John Tebbutt.

Occultations of *Ceres* and of *Venus* observed at the Cambridge Observatory. Communicated by Sir R. S. Ball.

Reply to Dr. Rambaut's note of the effect of chromatic dispersion. David Gill.

Right ascensions and declinations of eight stars in the constellation *Aquarius*; and their probable proper motions. C. J. Merfield.

Further researches on the orbit of γ *Lupi*$=h$ 4786. T. J. J. See.

On the actinic qualities of light as affected by different conditions of atmosphere. Rev. J. M. Bacon.

A second catalogue of the stars of the IV. type. Rev. T. E. Espin.

On the attempts to counteract by instrumental adjustments certain effects of refraction in stellar photography. A. R. Hinks.

Note concerning diffraction phenomena. H. F. Newall.

A diagram showing the conditions under which observations for the determination of stellar parallax are to be made. A. R. Hinks.

Observations of Comet *b* 1898 (*Perrine*) made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Nov. 11. Note on the level errors of the Cape transit circle. W. H. Finlay.

Ephemeris for physical observations of *Mars*, 1898. A. C. D. Crommelin.

The sidereal system revised in 1898. Maxwell Hall.

Observations of nebulæ. H. A. Howe.

List of nebulæ discovered at the Chamberlin Observatory, University Park, Colorado. H. A. Howe.

Observations of comet 1898 (Coddington, June 11) made at Sydney Observatory. Communicated by H. C. Russell.

Observations of the variable stars *U Orionis* and *T Centauri*. Col. E. E. Markwick.

Observations of *Jupiter* and *Jupiter's* satellites made at Mr. Crossley's Observatory, Bermerside, Halifax, during the opposition 1897–98. J. Gledhill.

Observations of *Jupiter* in 1898. W. F. Denning.

The great red spot on *Jupiter*. W. F. Denning.

Observations of Comet *h* 1898 (*Perrine—Chofardet*) made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Ephemeris for physical observations of *Mars*, 1898–99. A. C. D. Crommelin.

Remarks on Dr. Gill's paper in the *Monthly Notices* for 1898 June. A. A. Rambaut.

Note on Pogson's manuscripts relating to his proposed atlas of variable stars. Rev. J. G. Hagen.

On the south temperate current of *Jupiter*. A. Stanley Williams.

Nomenclature of the chief surface currents of *Jupiter*. A. Stanley Williams.

On a new instrument for measuring astrophotographic plates. David Gill.

On a method of obtaining perfectly circular dots un-

affected by phase, and their employment for determining the pivot errors of the Cape transit circle. David Gill.

On some photographs of the Moon, comets, meteors, and the Milky Way; and on the exterior nebulosities of the *Pleiades*. E. E. Barnard.

Mean areas and heliographic latitudes of Sun-spots in the year 1897, deduced from photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius. Communicated by the Astronomer Royal.

Observations of planet (433) (1898 DQ) with the 30-inch reflector of the Thompson equatorial at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

The division errors of the Greenwich transit circle. F. W. Dyson and W. G. Thackeray.

Observations of Comet *i* 1898 (*Brooks*) made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Approximate ephemeris of the part of the *Leonid* swarm through which the Earth passed in 1866. G. Johnstone Stoney.

Ephemeris for physical observations of *Jupiter*, 1898–99. A. C. D. Crommelin.

Dec. 9. Observations of the *Leonids*, 1898 November, made at the Cambridge Observatory. A. R. Hinks.

Note on the effect of wear on the errors of micrometer screws. David Gill.

Observations of comet Coddington (*c* 1898). John Tebbutt.

On a probable instance of periodically recurrent disturbance on the surface of *Jupiter*. W. F. Denning.

The extra-equatorial currents of *Jupiter* during the apparition of 1897–98. Rev. T. E. R. Phillips.

Discovery of comet *Brooks* 1898. W. R. Brooks.

The November meteors, observed at the Royal Observatory, Edinburgh. Communicated by the Astronomer Royal for Scotland.

Cometary observations at the Liverpool Observatory, 1897–98. W. E. Plummer.

Ephemeris for physical observations of the Moon for the first half of 1899. A. C. D. Crommelin.

Observations of Comet *i* 1898 (*Brooks*) made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of the *Leonid* meteors, 1898 November. Communicated by G. Johnstone Stoney.

1899.

Jan. 13. Observations of meteors made at the Royal Observa-

tory, Cape of Good Hope, 1898 November 13 and 14. Communicated by H.M. Astronomer.

Observations of planet (433) (DQ), made with the 30-inch reflector of the Thompson equatorial at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of the *Leonids*, 1898 November, made at Perth Observatory, Western Australia. Communicated by W. E. Cooke.

Preliminary description of the new photographic equatorial of the Cambridge Observatory. Sir R. S. Ball.

On the value of possible observations from free balloons. Rev. J. M. Bacon.

Note on Dr. Gill's paper "On a new instrument for measuring astrophotographic plates." H. H. Turner.

Note on Mr. Espin's object in *Perseus*. C. D. Perrine.

Eclipse of the Moon, 1898 December 27. Rev. W. Sidgreaves.

Note on a preliminary and unsuccessful attempt to photograph the corona without an eclipse. Rev. C. D. P. Davies.

The great Sun-spot of 1898 September. W. H. Robinson.

Occultations of stars during the lunar eclipse of 1898 December 27, observed at the Liverpool Observatory. W. E. Plummer.

Observations of occultations of stars and planets by the Moon and of phenomena of *Jupiter's* satellites, made at the Royal Observatory, Greenwich, in the year 1898. Communicated by the Astronomer Royal.

A suggestion for the explanation of stationary radiant points of meteors. H. H. Turner.

Remarks on Professor Turner's paper, together with another suggested explanation of stationary radiant points of meteors. A. S. Herschel.

Observations of the brightness of α *Orionis*, 1895–98. T. W. Backhouse.

Note on photographs of the satellite of *Neptune* taken with the 30-inch reflector and the 26-inch refractor of the Thompson equatorial at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of *Eros* (1898 DQ) made with the 30-inch reflector of the Thompson equatorial at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

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Marseilles, Flammarion Scientific Society.
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Paris, Philomathic Society.
Paris, Polytechnic School.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Pola, Meteorological and Magnetical Observatory.
Potsdam, Astrophysical Observatory.
Potsdam, Royal Prussian Geodetic Institute.
Prague, Imperial Observatory.
Rio de Janeiro Observatory.
Rome, Central Meteorological Office.
Rome, Italian Society of Sciences.
Rome, Italian Spectroscopic Society.
Rome, Pontifical Academy *de' nuovi Lincei.*
Rome, Royal Academy *dei Lincei.*
St. Petersburg, Imperial Academy of Sciences.
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Sydney, Royal Society of New South Wales.
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Vienna, Imperial Academy of Sciences.
Vienna, Imperial Military Geographical Institute.
Vienna, Imperial Ministry of Marine.
Vizagapatam, G. V. Juggarow Observatory.
Washington, Office of the American Ephemeris.
Washington, Smithsonian Institution.
Washington, United States Coast and Geodetic Survey.
Yale University, Astronomical Observatory.
Zurich, Central Meteorological Institute of Switzerland.
Zurich, Geodetic Commission of Switzerland.
Zurich, Natural History Society.
Editors of the "American Journal of Mathematics."
Editors of the "American Journal of Science."
Editor of the "Astronomical Journal."
Editor of "Astronomische Mittheilungen."
Editor of the "Astronomische Nachrichten."
Editors of the "Astrophysical Journal."
Editor of the "Athenæum."
Editors of the "Bulletin des Sciences Mathématiques."
Editor of the "English Mechanic."
Editor of "Himmel und Erde."
Editor of "Indian Engineering."
Editor of the "Naturwissenschaftliche Rundschau."
Editors of "The Observatory."
Editors of "Popular Astronomy."
Editor of "Sirius."

Herr H. Alsdorf.
M. Ch. André.
Sigr. F. Angelitti.
M. E. M. Antoniadi.
Prof. O. Backlund.
Sir R. S. Ball.
Prof. E. E. Barnard,
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Herr Leo Brenner.
Charles Bright, Esq.
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Sigr. V. Cerulli.
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T. R. Dallmeyer, Esq.
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Wm. Ellis, Esq.
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Dr. A. H. Fison.
M. R. Gauthier.
D. A. N. Grover, Esq.
D. E. Hadden, Esq.
Dr. B. Hasselberg.
Capt. E. H. Hills.
Prof. H. A. Howe.
Herr J. N. Krieger.
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M. A. Laussedat.
Miss Lecky.
Percival Lowell, Esq.
W. T. Lynn, Esq.
F. McClean, Esq.
Sigr. A. Mascari.
E. W. Maunder, Esq.
Arthur Mee, Esq.
Prof. R. Meldola.
Herr M. W. Meyer.
Prof. E. Millosevich.
Prof. K. D. Naegamvala.

G. J. Newbegin, Esq.
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M. G. Rayet.
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Sigr. A. Riccò.
Dr. Isaac Roberts.
H. C. Russell, Esq.
M. A. Rydzewski.
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Prof. W. Schur.
Robert Sewell, Esq.
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M. J. Skwortzow.
M. B. Snyder, Esq.
Dr. E. J. Spitta.
M. W. Stratonoff.
W. Teasdale, Esq.
John Tebbutt, Esq.
C. Thwaites, Esq.
Prof. D. P. Todd.
Mrs. Todd.
Prof. H. H. Turner.
Prof. H. C. Vogel.
F. L. O. Wadsworth, Esq.
Prof. L. Weinek.
A. Stanley Williams, Esq.
W. E. Wilson, Esq.
Prof. Max Wolf.
Dr. A. Wolfer.
Prof. C. A. Young.
Prof. C. V. Zenger.

ADDRESS

Delivered by the President, Sir Robert S. Ball, LL.D., F.R.S., on presenting the Gold Medal to Mr. F. McClean. LL.D., F.R.S.

THE Council have this year bestowed the Gold Medal of the Royal Astronomical Society on our distinguished Fellow, Mr. Frank McClean, in recognition of his important contributions to spectroscopic astronomy. In making this award, the Council have specially desired to mark with their approbation the zeal, the patience, and the success with which Mr. McClean has carried through his splendidly conceived scheme of photographing the spectra of all stars down to a certain limit of brightness over the whole surface of the celestial sphere.

To set before the Society some account of those researches which have been instrumental in deciding the Council to award to Mr. McClean the highest distinction in their power, I commence with a brief description of some of the earlier works of our medallist, the success of which induced him to undertake the great celestial survey that he has recently completed.

In 1890 November, Mr. McClean submitted to the Royal Astronomical Society an elaborate series of comparative photographs of the spectra of the High Sun and the Low Sun. This paper was accompanied by an Atlas of Plates, which constitute a beautiful piece of astronomical work.

The apparatus employed in this investigation consisted essentially of a heliostat commanding a large extent of the horizon, by which the solar light was reflected into a telescope parallel to the polar axis. The object-glass of this telescope had a focal length of 98 inches, and the aperture was stopped down o 4 inches. A right-angled prism near the focus reflected the olar image horizontally into the spectroscope, which consisted f a pair of collimating and observing telescopes, each of 2 inches perture. These are fixed at an inclination of 16° 30′, and at heir intersection is a Rowland grating. Many interesting etails are recorded with regard to the absorption screens that Ir. McClean found useful for the different parts of the pectrum.

The Atlas of Plates contains spectra of the High Sun, when

the altitude was as much over 45 degrees as possible, and of the Low Sun, when the altitude was under $7\frac{1}{2}$ degrees. The elastic force of aqueous vapour present in the atmosphere, on each occasion, has been duly recorded. The whole length of the spectrum has been divided into thirteen sections corresponding to Ångstrom's scale. In the production of the Atlas the original negatives have been magnified about $8\frac{1}{2}$ times. Each section is thus 35 cms. long, the width of the spectrum being nearly 6 cms. To facilitate the comparison between the spectra of the Sun when high, and the Sun when low, the photographs are placed in juxtaposition, so that corresponding lines are continuous.

An inspection of these remarkable plates brings out in a striking manner the varied effects of atmospheric absorption on the light of the spectrum, in accordance with the variations of solar altitude. Mr. McClean divides the groups of lines which are specially under atmospheric influence into two classes. Firstly, there are groups in which the majority of the lines grow uniformly darker as the Sun approaches the horizon. Secondly, there are groups in which individual lines become exceptionally prominent in the spectrum of the Low Sun, these effects being specially noticeable when there is much moisture in the air. Among the groups of the first class we may mention those about A, as well as those about B, while among many instances of the second class, the well-known groups near D form specially remarkable features in Mr. McClean's plates. It will, of course, be understood that these photographs are not put forward for the purpose of determining any fundamental measurement. "They are," to use the author's own words, "only suitable for the identification of groups of lines, and for filling in the details between standard lines whose wave lengths have been determined by direct observations with proper instruments."

Another piece of important work which has to be classed among the preliminary labours of our medallist is his study of the comparative photographic spectra of the Sun and the metals. In a second Atlas, on about the same scale as that to which I have just referred, two fine series of photographs are contained. The first series comprises the metals of the Platinum group, and exhibits, in six sections, the spectra of iron, platinum, iridium, osmium, palladium, rhodium, ruthenium, gold and silver.

The second series contains elements of the Iron-Copper group, and presents, in six sections, the spectra of iron, manganese, cobalt, nickel, chromium, aluminium, copper.

The original negatives were taken with a Rowland plane grating, ruled with 14,438 lines in an inch, and with an observing telescope of about 36 inches focal length. These negatives were then enlarged about $8\frac{1}{2}$ times, and mounted in juxtaposition, so that corresponding lines of each spectrum form continuous vertical lines on the plate.

The sections into which the spectra have been divided, like those of the photographs of the solar spectrum already referred

to, have been arranged to accord with the well-known divisions of Ångström's solar spectrum. The student will find it an additional convenience that the scale adopted by Mr. McClean is also very nearly that of Ångström's map. The top and bottom of every plate are bounded by the solar spectrum, while immediately inside, at each end, is the iron spectrum obtained by sparking through air. Between the two iron spectra thus conveniently placed for comparison the bulk of the plate contains the spectra of the other metals. In the case of the Platinum group there are eight of these intermediate metals.

In the series of plates illustrating the Iron-Copper group the iron spectrum, as before, is placed immediately inside the solar spectrum, both at the top and the bottom, and the six other elements provide the intervening spectra. A striking feature on these plates is afforded by the broad lines and bands extending vertically down the plate which are due to the atmosphere. This spectrum is, of course, necessarily introduced when the induction spark is taken between metal electrodes in the air. With reference to these spectra, I cannot do better than quote Mr. McClean's own words :

"Before the true spectra of the metals can be arrived at, it is necessary to further eliminate the lines due to various impurities in the specimens of the metals employed as electrodes. Iron appears in the spectrum of aluminium, and to a less degree in other spectra. Calcium is almost universally present, and becomes especially prominent throughout Section I. Its principal lines run with varying strength across nearly every spectrum, and coincide with marked groups of lines in the solar spectrum. The calcium spectrum appears most strongly in osmium and cobalt. The principal barium lines are also present in osmium, and its complete spectrum is no doubt present in Section I."

"The beautiful fluting lines in Section IV. of the aluminium spectrum is attributed by Thalén to the oxide of aluminium formed in the aureole of the induction spark. The similar well-defined but less-marked fluting which occurs in many of the spectra in Section I. must be due to one of the constituents of the air. It cannot be due to calcium, for it is prominent in metals where calcium is absent."

But the chief work of Mr. McClean's scientific career, and the work which has mainly influenced your Council in awarding to him the Gold Medal of the Royal Astronomical Society, has been his great spectroscopic survey of all the brighter stars in the heavens. The project which Mr. McClean formed, and which he succeeded in accomplishing, was to obtain a photograph of the spectrum of every star not less bright than 3½ magnitude in both celestial hemispheres.

His first task was to effect a partition of the celestial sphere into regions which should be convenient for reference, while at the same time the lines of partition should be those naturally

suggested by the character of the research which was to be undertaken. The ordinary subdivision into constellations was here, at least, quite unsuitable.

Mr. McClean somewhat daringly abandoned the celestial Equator when he required to effect the prime partition of the celestial sphere into two hemispheres. The sublime conception which each bright starlight night suggests to the reflective observer was adopted by your medallist. He took as his fundamental great circle that which as nearly as possible conforms to the path of the Galaxy. We are therefore to understand in these researches that the celestial pole is no longer the pole of the meridian astronomer or the navigator. It is, indeed, the true sidereal pole, the point nearly 90 degrees from the Galaxy; it is the pole of the Milky Way.

If a circle be drawn at a radius of 60 degrees from the North Galactic Pole, we obtain the first of Mr. McClean's partitions of the sphere; the area comprised within that segment is, of course, one-fourth of the entire spherical surface. Another fourth of the area would be comprised between this circle and the fundamental great circle, which we may perhaps describe as the Galactic Equator. The hemisphere containing the south pole of the Galactic Circle is to be similarly divided into a polar cap of 60 degrees radius and a zone bordering the equator 30 degrees broad. Thus the entire sphere is divided into four regions of equal extent. To carry the partition yet one stage further, a plane of section has been drawn through the Galactic axis. The choice of this plane was determined by the necessity for a convenient distinction between the celestial regions easily seen from stations in the Northern Hemisphere and those which required an observer in the Southern Hemisphere.

The two North Polar lunes are referred to by the symbols A and AA, the South Galactic Polar lunes are D and DD, the northern zones adjoining the Equator are B and BB, and the southern zones adjoining the Equator are C and CC.

As the scheme contemplated by Mr. McClean embraced a survey of the whole heavens, it was necessary to divide it into two parts; an observing station was therefore required in each hemisphere. The survey of the Northern Hemisphere was naturally conducted from the Observatory at Mr. McClean's residence at Rusthall, Tunbridge Wells; for the study of the Southern Hemisphere Mr. McClean proceeded to the Cape of Good Hope, and there availed himself of the assistance kindly rendered to him by Dr. David Gill at the famous Observatory over which Her Majesty's Astronomer so worthily presides. It is to this great and important work that I now invite your attention.

In both hemispheres alike Mr. McClean has found it necessary to introduce a classification of the spectra of the stars into a series of divisions as far as possible parallel to the types long associated with the name of Secchi. The first of the types described by Secchi has been subdivided for the present work

into three divisions, and then Secchi's second, third, and fourth types are identified respectively with the fourth, fifth, and sixth divisions used by Mr. McClean.

Division I. includes all stars whose spectra are characterised by possessing lines similar to those yielded by what Mr. McClean designates as Cleveite gas, in addition to the lines of Hydrogen. It has been found necessary to subdivide still further this division, inasmuch as the spectra of some of the stars which have to be included in the first division show other special lines in addition to those already mentioned. A comparison of the spectra of these stars with Campbell's photograph of the bright-lined spectrum of the great nebula in *Orion* has proved very instructive. Mr. McClean remarks that the general coincidence of the lines in the photograph of the nebula with the lines in the photographs of the stars of the first division leaves little doubt as to the close connection between stars of this denomination and the nebulæ specially designated as gaseous.

A remarkable parallelism between the distribution of the Helium stars of Division I. and the gaseous nebulæ must not be overlooked. Here we at once realise the special advantage of that form of division of the celestial sphere which has been adopted. By comparing the Table of Gaseous Nebulæ in Frost's edition of Scheiner's *Spectroscopy* with the list of the stars characterised by the Helium spectrum, a remarkable analogy is manifest. This is illustrated by the figures here shown :—

	Regions.			
	A.	B.	C.	D.
Gaseous nebulæ	3	7	16	6
Stars of Division I.	3	6	17	3

The second division in Mr. McClean's sidereal classification contains those stars which have spectra of the Hydrogen type. In this class of star the Hydrogen exhibits its full development, both in the strength of the individual lines and in the number in which they are present. The beautiful ultra-violet series of lines are a special feature of such spectra. The third and last of the separate divisions, which together make up Secchi's Type I., contain stars of the Hydrogen-Iron type, in some of which the iron is more fully displayed than it is in others. The fourth division recognised by Mr. McClean, equivalent as it is to Type II. according to Secchi, includes stars which have spectra of a solar character, while the fifth and the sixth divisions are, as already mentioned, equivalent to the well known Types III. and IV.

It will give some idea of the scope of Mr. McClean's work to mention that in the region A he has photographed 35 stellar spectra, in B 31, in C 38, and in D 26, while in AA he obtained 30. The remaining regions were not to be studied until this industrious observer made his expedition to the Southern Hemisphere.

The photographs which were taken at Rusthall occupy 17 plates in the *Philosophical Transactions of the Royal Society for* 1898. In a work so extensive it is difficult to select a part for special notice. I may, however, venture to offer as a typical illustration of Mr. McClean's skill the plate marked C in the lower Galactic zone north. There we have the spectra of γ *Orionis*, Algol, and Rigel, while for comparison, Runge and Paschen's spectrum of Cleveite gas has been added.

The important labours of Mr. McClean in the exploration of the spectra of the brighter stars in the Southern heavens have now to be described. I am able to discharge this duty the more readily because he has himself provided an admirable account in his work entitled *Spectra of Southern Stars* (Stanford, 1898).

Recalling the method by which Mr. McClean divided the celestial sphere into eight regions, it will be observed that from Rusthall he was able to conduct the exploration of A, B, C, D, and AA; the three regions on which his attention had to be concentrated at the Cape of Good Hope are therefore BB, CC, DD. These are respectively the southerly halves of the upper Galactic zone, the lower Galactic zone, and the South Polar zone.

Mr. McClean worked at the Cape of Good Hope from May to November 1897. Northern astronomers will read with mingled feelings the record which Mr. McClean gives us of the purity of the skies in South Africa. It appears that during the six months on which he was engaged in his task he had no fewer than 76 perfectly clear nights in addition to many others which were partly suitable for refined astronomical work. He was thus able to obtain 292 photographs of stellar spectra, the total number of different stars being 116.

Dr. Gill placed at the disposal of his visitor the well-known astrographic instrument that has already been used with such energy and success at the Cape. In front of the object glass of this telescope Mr. McClean fitted his refracting prism of 12 inches in aperture and 20 degrees refracting angle. Thus the equipment with which his work was conducted in the Southern Hemisphere was practically identical with that which he had employed in the first part of his work at Rusthall. The advantage of this symmetry in the method of conducting the survey is obvious, and will be appreciated by every one who has occasion to use the two series of beautiful plates.

One of the most instructive facts that is brought out by the Tables in which the results of the observation are embodied, relates to the distribution of the stars of Division I., or, as Mr. McClean frequently designates them, the "Helium" stars. The features brought out fully justify the choice of that particular partition of the celestial sphere which he has adopted. It is obvious that these Helium stars are strewn not at all uniformly over the surface of the heavens. They are mainly congregated in

the two zones north and south of the Galactic Equator. This fact, now so clearly established, seems to point to some fundamental characteristics in the distribution of the sidereal masses on the nature of which perhaps it would be premature at present to speculate.

It should be observed that the remarkable tendency of Helium stars to appear condensed along the Galaxy is peculiar to stars of this particular division. Stars belonging to the other divisions do not seem, so far as Mr. McClean's lists inform us, to exhibit any similar relation to the Milky Way. For example, the stars of the solar type seem to appear with fairly uniform frequency over all the eight regions of the sphere, and a like statement may be made with regard to the stars of the remaining types.

It was, I believe, Sir John Herschel who first drew attention to the fact that the sidereal objects in the southern heavens considerably surpass in interest, in variety, and in splendour, the objects with which astronomers in our Northern Hemisphere are so familiar. An illustration of the truth of this principle may be derived from an examination of the distribution of the Helium stars as set forth in Mr. McClean's tables. Not only are the stars of this particular class concentrated in the immediate neighbourhood of the Galaxy, but they are largely confined to a particular part of that luminous girdle just as a group of Wolf-Rayet stars is found in *Cygnus*. It unfortunately happens, at least so northern astronomers will think, that the regions of the Galaxy where the Helium stars most delight to congregate are precisely those parts of the Galaxy towards which their spectroscopes can never be directed. Mr. McClean remarks how this feature in the stellar distribution may be strikingly shown by marking off the Helium stars in the Key Chart of *Gould's Uranometria Argentina*. From *Perseus*, through the south to *Sagittarius*, the Helium stars are almost entirely congregated within the limit of the Galaxy.

In the work I have already cited will be found certain tables in which Mr. McClean has collected the result of his labours into a concise form full of interest and suggestiveness. In some of them he has included figures derived from his labours at Rusthall, so that in many respects these tables present a survey of the complete heavens. Thus we find that there are, in all, no fewer than 88 stars of Division I., not of course going below the standard limit of the $3\frac{1}{2}$ magnitude. The unequal distribution of these stars, to which we have already referred, is well brought out by the fact that while no more than 18 are to be found in the North and South Galactic Polar regions, no fewer than 70 lie in the two zones on either side of the Galactic Equator. The doctrine of probability assures us that it can be no mere accident which permits one-half of the celestial sphere to have almost four times as many of these particular objects as are contained in the other half.

But the table which perhaps most specially illustrates our medallist's work in the Southern Hemisphere is that containing an elaborate comparison between the spectrum of the celebrated star *β Crucis* and the spectra of Helium, Hydrogen, and Oxygen. In this table he has recorded the result of the measurements of the photographs which are to be seen on Plate 12.

About 100 lines in the spectrum of *β Crucis* are set forth. These lines have been measured on the plates in the usual manner, and then these measurements have been transformed into wave-lengths from their original expression in millimetres. For this transformation formulæ of interpolation have been employed. Each formula involved four constants, and for the determination of these constants four characteristic lines of Helium have been taken as standards. The wave-lengths of these standard lines being known from Rowland's scale, the four constants of the formulæ were determined. By substitution in the formula of the scale position of any other line its wave-length was therefore known. Mr. McClean has set down in his table the wave-length thus ascertained of the several lines in the spectrum of *β Crucis*.

The agreement between the lines of Helium in the spectrum of this star and the lines measured by Runge and Paschen in the spectrum of the same element obtained from terrestrial sources, are very remarkable. There are about 20 lines common to the two spectra, and the residual differences between the determinations of their wave-lengths are insignificant. The range of these lines, adopting the usual method of representation, vary from wave-length 380·59 up to 492·21. There is also a comparison of the lines in the spectrum of Hydrogen, as determined by Ames, with certain other lines in the spectrum of *β Crucis*. Here again the agreement is satisfactory.

But more than half the lines in the spectrum of this particular star form what Mr. McClean calls the *extra* lines. They belong to neither Hydrogen nor Helium, and the claim made for their interpretation is perhaps the most characteristic feature of this part of Mr. McClean's work. With the object of accounting for these lines, Mr. McClean gives, in a special column, the wave-lengths of lines characteristic of the spectrum of Oxygen as observed by Neovius. Between forty and fifty of these lines appear from this table to agree well with lines in the spectrum of *β Crucis*. I may take as examples of the series both the first and the last. There is a line in the star spectrum whose wave-length as determined by the formula of interpolation is 407·02. This is naturally compared with an Oxygen line that falls according to Neovius at 407·01.

A table on page 14 of Mr. McClean's work must, however, be consulted in connection with the interesting interpretation which he proposes for these extra lines. A list is there given of lines attributed by Neovius to Oxygen, but apparently absent from the spectrum of *β Crucis*. This important subject merits

most scrupulous examination by spectroscopists, and to their consideration may be commended the words of our medallist, that :

"Taking everything into account, the succession of coincidences between the extra lines of β *Crucis* and the Oxygen spectrum can only be accounted for on the basis of the extra lines being in the main actually due to Oxygen."

Astronomers will turn with special interest to learn what Mr. McClean's researches at the Cape have disclosed with reference to that particularly interesting star γ *Argus*. The photograph of its spectrum on Plate 12 shows in a striking manner the bright lines characteristic of this typical Wolf-Rayet star. The spectra of β *Crucis*, of β *Centauri*, and of β *Can. Maj.*, which are placed in juxtaposition, fully justify Mr. McClean's announcement that γ *Argus* is also to be regarded as a Helium star. Towards the close of this volume several statements occur that will have a still further interest for astronomers, inasmuch as they seem to point to the unlimited fields of work opening up before those spectroscopists of the future who may have the happiness to work in Southern climes. I may mention, in illustration of this remark, that Mr. McClean has found several cases in which the two components of a Double Star are each of the Helium type. We also learn that a fine Helium star in *Argus* is accompanied by a group of small Helium stars, while he further tells us that a small group of Helium stars are adjacent to π *Argus*, a solar star.

It is impossible for me on an occasion like the present to forbear from any mention of the splendid benefactions by which Mr. McClean has also striven to further the cause of astronomy. As founder of the Isaac Newton Studentships at Cambridge, and as donor of the magnificent photographic telescope at the Cape, he has rendered services to the advancement of astronomy of which this generation is already reaping the fruits, and which will be even more useful in the generations to come. But I need hardly inform you that the award of this medal has, in the view of the Council, been made in recognition not of Mr. McClean's position as a splendid patron of our science but in recognition of his position as a faithful toiler in our ranks. We know that, disdaining to live a life of inglorious ease, he has elected to follow with vigour, with skill, and with success, an arduous and difficult branch of astronomical work.

Let it be also noted that in the performance of his great task Mr. McClean did all the work himself. He employed no staff of assistants. He had not even a single assistant to lighten his labours in his laboratory by day or to relieve him in the observatory by night. Those long vigils in both hemispheres were not, I can assure you, observed by deputy. Your medallist was not content with merely designing the arrangements for the survey. Every detail of the work he has carried through himself. It was he that exposed those plates to the heavens through the long silent hours of darkness. The critical duty of developing those

plates was never entrusted to any other hand than his own. He it was who subsequently gave the enlargement necessary for publication ; it was his eye that measured the lines, and his was the pen that worked out the calculations. Need I add more to prove that what Mr. McClean's hand had found to do he did with all his might. The lofty principle that inspired his work was the love of truth, and we are assembled here to-day not less to do honour to the spirit in which his work was undertaken than to do honour to the work itself.

In the name of the Royal Astronomical Society, I therefore hand this gold medal to Mr. McClean as the visible token of our admiration for his spectroscopic survey of stars in both celestial hemispheres.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:

President.

G. H. Darwin, Esq., M.A., LL.D., F.R.S., Plumian Professor of Astronomy, Cambridge.

Vice-Presidents.

Capt. W. de W. Abney, C.B., R.E., D.C.L., F.R.S.
Sir R. S. Ball, M.A., LL.D., F.R.S., Lowndean Professor of Astronomy and Geometry, Cambridge.
W. H. M. Christie, Esq., C.B., M.A., F.R.S., Astronomer Royal.
J. W. L. Glaisher, Esq., M.A., Sc.D., F.R.S.

Treasurer.

E. B. Knobel, Esq.

Secretaries.

F. W. Dyson, Esq., M.A.
H. F. Newall, Esq., M.A.

Foreign Secretary.

Sir William Huggins, K.C.B., LL.D., D.C.L., F.R.S.

Council.

A. A. Common, Esq., LL.D., F.R.S.
A. M. W. Downing, Esq., M.A., D.Sc., F.R.S., Superintendent of the *Nautical Almanac.*
John Evershed, Esq., Jun.
Capt. E. H. Hills, R.E.
Frank McClean, Esq., M.A., LL.D., F.R.S.
Major P. A. MacMahon, R.A., F.R.S.
W. H. Maw, Esq.
Capt. William Noble.
A. A. Rambaut, Esq., D.Sc., Radcliffe Observer.
G. M. Seabroke, Esq.
W. G. Thackeray, Esq.
H. H. Turner, Esq., M.A., B.Sc., F.R.S., Savilian Professor of Astronomy, Oxford.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIX. MARCH 10, 1899. No. 6

Professor G. H. DARWIN, M.A., LL.D., F.R.S., President, in the Chair.

Col. Thomas Davies Sewell, 29 Grosvenor Road, S.W.,

was balloted for and duly elected a Fellow of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

The Rev. Edward Lyon Berthon, M.A., St. Margaret's, Cupernham, Romsey, Hants (proposed by Sir Howard Grubb) ;

The Rev. Theodore Evelyn Reece Phillips, M.A. (Oxon.), Hendford Vicarage, Yeovil, Somerset (proposed by W. F. Denning).

One hundred and twenty presents were announced as having been received since the last ordinary meeting, including, amongst others :—

A. Berry, A short history of Astronomy, presented by the author ; V. de Campigneulles, Observations of the eclipse of 1898 January 22, by the Jesuit Fathers of the Western Bengal Mission, presented by St. Xavier's College Observatory ; A. H. Fison, Recent advances in Astronomy, and A. Laussedat, Recherches sur les instruments topographiques, tome 1, presented by the authors ; Columbia University Observatory, New York, Collected

Contributions, vol. i., presented by the Observatory; Potsdam Observatory, Publications, vol. 12, pt. 1, vol. 13, presented by the Observatory; E. J. Spitta, Photo-micrography, presented by the author; Mrs. Todd, Corona and Coronet, being a narrative of the Amherst Eclipse Expedition to Japan, 1896, presented by the author; The Second Washington Catalogue of Stars, presented by the U.S. Naval Observatory; Photographischer Mond-Atlas, part 4, presented by L. Weinek; Photographs of the total solar eclipse of 1898 January 22, presented by C. Burckhalter; Photographs of artificial lunar formations, presented by S. H. R. Salmon; Photographs of fields of stars showing trails of minor planets, &c., presented by Max Wolf.

Report of the Proceedings of the Sydney Observatory for 1898.*

Reference was made in the Report for 1897 to the difficulty introduced into our photographic work by the adoption of incandescent gas-burners for illuminating the city. The light given by these incandescent burners is powerfully actinic, and the dust and smoke of a great city reflects enough of this light to fog long-exposure plates.

To avoid this unexpected difficulty, the Government has granted a sum of money for the removal of the star camera from the city to the site selected some years since for the Observatory. The experiments then made proved that the atmosphere was very much clearer than in the city, so much so that a three hours' exposure there was equal to one of five hours in the city. Red-hill, the place referred to, is 615 feet above the sea and eleven miles W.N.W. from the present Observatory.

Measurement of Photographic Plates.—An arrangement has been made by which the measurement of our star plates will at last be undertaken systematically.

The Governments of Victoria and New South Wales have granted the money necessary for measuring the photographic plates, and at a conference of the astronomers of Melbourne and Sydney it was decided to combine the money grants, with the object of making one complete measuring bureau, furnished with the most perfect measuring machines. The work will be done in Melbourne, and the staff is now being trained by Mr. Baracchi.

Transit Circle.—With the transit circle (only one observer) 1,355 transits and 511 meridian zenith distances have been observed. The computations of the meridian observations have

* This report was received unfortunately too late for insertion in the Annual Report of the Council.

been completed, and a large volume of arrears in printing now awaits publication.

The daily determinations of collimation, level, and nadir, for determining the progressive motion of the meridian circle, have been continued.

Double Stars.—With the equatorial (one observer) 98 double stars have been measured. 444 position-angle settings and 458 measures of distance were taken.

Comet *Coddington* was observed, and ninety-eight comparisons made with fifteen stars. The transit circle was used fourteen times to determine the comet's position on the meridian.

Star Camera.—With the star camera 247 photographs were taken with 326 exposures. Of these, 152 are chart plates and eighty-eight catalogue plates, and seven on special subjects.

The year has been remarkably dry and dusty, so much so that many nights were too dusty to permit taking photographs.

Meteorology.—The meteorological work has been carried on as usual. The increase in the number of stations goes on, and now they number 1,610. The volume for 1897 has been printed and distributed, and that for 1898 is nearly ready for the press.

During the year there has been added to the recording machines at the Observatory a new form of recording thermometer, which is as sensitive as the ordinary mercurial thermometer.

The usual inspection of meteorological stations has been carried out.

General.—During the year three books and five pamphlets have been published and distributed—in all 4,620 copies have been sent out; and rain and weather charts to the number of 1,800 copies have been distributed.

985 publications of other Observatories have been received and acknowledged.

Visitors show no sign of falling off, rather the reverse. During the year 1,207 visitors came to the Observatory. This is the penalty of having the Observatory in the heart of a large city.

Determination of the Diameter and Compression of the Planet Mars from Observations with the Repsold Heliometer of the Royal Observatory, Göttingen. (*Second Communication.*) By Professor W. Schur.

Near the opposition of the present year the following measurements of the polar and equatorial diameters of the planet *Mars* were made, the images being steady :—

Date, 1899.	Mean Time, Göttingen.	Areographic Latitude.	Measured Diameter.		Diameter at Mean Distance from the Sun.	Mean of *h* and *v*.
	h m	°				
January 21	8 44	90	14″·74	*h*	6″·33	6″·23
			14·50	*v*	6·23	
		0	14·62	*h*	6·28	6·34
			14·90	*v*	6·40	
		0	14·63	*v*	6·29	6·28
			14·59	*h*	6·27	
		90	14·33	*v*	6·16	6·18
			14·43	*h*	6·20	
		90	14·52	*h*	6·24	6·38
			15·15	*v*	6·51	
		0	14·40	*h*	6·19	6·40
			15·36	*v*	6·60	
		0	15·41	*v*	6·62	6·46
			14·63	*h*	6·29	
		90	14·75	*v*	6·34	6·26
			14·36	*h*	6·17	
January 23	13 15	90	14·59	*h*	6·30	6·24
			14·28	*v*	6·17	
		0	14·24	*h*	6·15	6·22
			14·56	*v*	6·29	
		0	14·21	*v*	6·14	6·21
			14·51	*h*	6·27	
		90	13·87	*v*	5·99	6·05
			14·12	*h*	6·10	
		90	13·87	*h*	5·99	6·07
			14·23	*v*	6·14	
		0	14·23	*h*	6·14	6·17
			14·36	*v*	6·20	
		0	14·26	*v*	6·16	6·14
			14·14	*h*	6·11	

Date, 1899.	Mean Time, Göttingen.	Areographic Latitude.	Measured Diameter.		Diameter at Mean Distance from the Sun.	Mean of *h* and *v*.
	h m	°	″		″	″
January 23	13 15	90	13·90	*v*	6·00	5·97
			13·76	*h*	5·94	
January 26	12 19	90	14·01	*h*	6·11	6·13
			14·07	*v*	6·14	
		0	14·35	*h*	6·26	6·30
			14·53	*v*	6·34	
		0	14·34	*v*	6·25	6·22
			14·17	*h*	6·18	
		90	14·05	*v*	6·13	6·17
			14·23	*h*	6·20	
		90	13·96	*h*	6·09	6·11
			14·03	*v*	6·12	
		0	14·30	*h*	6·24	6·32
			14·65	*v*	6·39	
		0	14·41	*v*	6·28	6·30
			14·47	*h*	6·31	
		90	14·16	*v*	6·17	6·17
			14·14	*h*	6·17	

As in the former communication (*Monthly Notices*, 1897, January), *h* and *v* denote the measurements with apparent horizontal and vertical motion of the images by means of the ocular reversing prism. The small correction for defect of illumination is taken from the ephemeris of Mr. Crommelin in the *Monthly Notices*. On January 21 in the second part the images were sometimes a little unsteady and blurred; hence the larger discrepancies.

If the results obtained 1896 December are combined with those of the present year, we have the following summary, including some small later corrections:—

	2*a*.	2*b*.	Diff.	$e = \frac{a-b}{a}$	
1896 Dec. 2	6″265	6″125	0″140	1 : 45	
11	6·310	6·135	0·175	36	Opposition Dec. 10.
16	6·210	6·095	0·115	54	
17	6·235	6·125	0·110	57	
1899 Jan. 21	6·370	6·263	0·107	60	
23	6·185	6·082	0·103	60	Opposition Jan. 18.
26	6·285	6·145	0·140	45	

The observations of the present year confirm those of 1896, and the planet would therefore have a compression of a fiftieth.

This result is to be preferred to that of earlier researches which have in part led to a similar value, since in the recent observations the use of an ocular reversing prism eliminates those peculiarities of the eyes of the observers which give rise to different results in measuring diameters of discs in different directions with the vertical line. The results of observations with the Göttingen heliometer have therefore a greater weight. (Compare the exhaustive researches of E. Hartwig, *Publication der Astronomischen Gesellschaft*, vol. xv.)

The result of the Gottingen heliometer observations is in conflict with that which Hermann Struve has calculated from his researches on the motions of the apsides of the satellites *Phobos* and *Deimos* (*Astronomische Nachrichten*, vol. cxxxviii, p. 228), *i.e.* $\frac{1}{190}$. One might be inclined to prefer the result of Struve, as there the compression is deduced from the perturbations in the motions of the satellites, but it should be remembered that the measured positions of the satellites, referred to the centre of the planet, are likewise founded upon comparisons with different points in the circumference of the disc, and that therefore errors may arise similar to those occurring in the heliometer observations. Respecting the latter, I must remark that in the opposition of this year the northern polar snow cap was visible in considerable extension and intensity, and that therefore the measurements of the polar diameter were rather difficult. But, as Hartwig has already shown on p. 54 of his treatise, this disturbing influence would not act in such a way as to diminish the polar diameters, but, on the contrary, to enlarge them, and therefore could not explain that difference.

In a recent publication (*Annals of the Lowell Observatory*, vol. i., "Observations of the Planet Mars during the Opposition of 1894–95," p. 75), Mr. Percival Lowell finds a value for the compression in good accordance with H. Struve, *i.e.* $\frac{1}{190}$; but it is not shown whether these observations are independent of errors in estimation—which in the case of the Göttingen heliometer measures are provided against by the use of the ocular prism—and I am of opinion that in all researches relating to the form of a celestial body this point is a necessary condition.

To reduce the diameters to the mean distance between Sun and Earth, the foregoing values of $2a$ and $2b$ are to be multiplied by 1·5227, and we have :—

$$2a = 9''\cdot 55 \qquad 2b = 9''\cdot 35.$$

Or, if we decline to adopt the great value of compression, the mean diameter of the planet *Mars* is $9''\cdot 45$.

It is to be hoped that observers with other heliometers have taken the opportunity to contribute to the settlement of this question.

1899 *February*.

The Radiant Point of the April Meteors (Lyrids).
By W. F. Denning.

On Wednesday morning, 1803 April 20,* a brilliant meteoric shower was observed from Richmond, Va., Raleigh, N.C., Wilmington, Del., Schoharie County, N.Y., Portsmouth, N.H., and at several places in Massachusetts. The phenomenon was variously described according to the different impressions received by the observers. One said "the shooting stars were too numerous to be counted"; another stated that "the heavens seemed to be all on fire from the abundance of lucid meteors." The *Virginia Gazette* in alluding to the event said that "from one to three in the morning meteors seemed to fall from every point in the heavens, in such numbers as to resemble a shower of sky-rockets. The inhabitants happened at the same hour to be called from their houses by the fire bell, which was rung on account of a fire which broke out at the Armoury, so that everyone had an opportunity of witnessing this grand scene of Nature."

In 1838 April 20 Professor Wright and an assistant at Knoxville, Ten., counted 154 shooting stars between 10^h and 16^h. In 1839 April 18 Herrick watched for the return of the shower, and in the three hours following midnight he and another observer counted 58 meteors. Herrick placed the radiant at $273°+45°$ between *Lyra* and the head of *Draco*. In 1842 April 20 he re-observed the shower, and in spite of moonlight 151 meteors were seen by five observers between $10^h\ 20^m$ and 16^h. The maximum hourly rate was 55 between 15^h and 16^h, and the

* Ancient showers, probably of Lyrids, are mentioned by Biot, Chasles and Herrick. They have been summarised by Professor H. A. Newton in the *American Journal of Science and Art*, vol. xxxvi., p. 145, and he points out that the time of occurrence of the shower has advanced 24 hours in 60 years, owing to the precession of the equinoxes. The dates and corresponding modern epochs of the ancient displays are as follows:—

Authority.	Date.						
Biot	B.C. 687	March	16	equivalent to	A.D. 1850	April	19·9
Biot	„ 15	„	25	„	„	„	19·6
Chasles	A.D. 582	„	31	„	„	„	18·1
Chasles	„ 1093	April	9·6	„	„	„	20·7
Chasles	„ 1094	„	10	„	„	„	20·8
Herrick	„ 1095	„	9·6	„	„	„	20·2
Herrick	„ 1096	„	10	„	„	„	21·3
Herrick	„ 1122	„	10·6	„	„	„	20·2
Chasles	„ 1123	„	11	„	„	„	20·4
				Mean date . .	1850	April	20·1

The conformity of dates renders it extremely probable that the old observations refer to veritable returns of the Lyrids.

radiant point was thought to lie in *Corona Borealis*. The shower was again witnessed in 1849 April 19, when 54 meteors were counted in an hour by Herrick and two others. In 1850 April 20 an extraordinary display of meteors was witnessed at Bombay; and the shower which occurred in 1863, and was favourably seen in England, was judged to equal a moderately strong return of the *Perseids*, for meteors from the *Lyrid* radiant were falling at the rate of about 40 per hour.

Without, however, touching further upon the historical associations of the display it may be said that when in 1866 the April meteoric shower came to be associated with Thatcher's comet, 1861 I., the observed radiant point of the former did not correspond with the computed radiant for the comet to within 7 degrees. Later determinations were somewhat more satisfactory, and I found on closely watching the returns of the shower in 1878–79 and several subsequent years that the cometary and meteoric radiants were identical.

From my observations in 1885 I concluded that the *Lyrids* formed a radiant which, like the *Perseids* of August, moved eastwards amongst the stars from night to night. In 1887 my results supported those of 1885, but indicated a displacement less in extent, though the same in direction. But the evidence of the shifting of the radiant can hardly be regarded as demonstrated, for it is necessary in meteoric work of this kind to proceed with extreme caution, the research being surrounded with difficulties of no ordinary kind. During the present generation the shower of Lyrids has been comparatively feeble, and the display has been limited to very few nights, so that it is not feasible to gather a large number of observations, as may be done in the case of the Perseids.

Meteors are often singularly rare at this particular season of the year. After making allowance for time spent in registering paths the average horary rate of appearance for one observer, on the nights from April 18 to 22 inclusive, is only 8, including Lyrids; but if these are excluded, the rate is reduced to 5. This scarcity of meteors is not confined to this special epoch; it operates generally during the whole of the first half of the year. But though meteors are usually so rare, there is quite a swarm of feeble radiants contemporary with the Lyrids, and, selecting a few of the most prominent, they are at

$$202^\circ+9^\circ,\ 213^\circ+53^\circ,\ 217^\circ-9^\circ,\ 218^\circ+33^\circ,\ 228^\circ-2^\circ,\ 231^\circ+17^\circ,$$
$$252^\circ-21^\circ,\ 263^\circ+62^\circ,\ 272^\circ+21^\circ,\ 296^\circ\pm0^\circ,\text{ and }302^\circ+23^\circ.$$

Many others are visible, but the great feebleness of these streams is a bar to their general detection, unless the firmament is watched during the whole night, or, better still, throughout several successive nights. At this season an observer may sometimes watch a beautifully clear, moonless sky for an hour or more

without noticing a single shooting star, and may be led to suppose, from the stillness of the firmament, that not a single meteoric stream is in play; but if he perseveres in his observations during 15 or 20 hours on a few following nights a considerable number of minor radiants will gradually and accurately manifest themselves in various parts of the heavens.

A summary of my observations of the Lyrids during the epoch from April 16 to 26 1873–98 is given in the following table :—

Date, 1873–98.	Hours of Observation.	Total No. of meteors seen.	Lyrids.	Radiant Point.
April 16	3	14	3	$263^\circ + 33^\circ$
17	4½	21	...	...
18	12¼	67	13	$266 + 33$
19	18¾	123	45	$268{\cdot}6 + 32{\cdot}3$
20	19	141	62	$272{\cdot}4 + 32{\cdot}8$
21	15	88	20	$272{\cdot}5 + 33{\cdot}5$
22	8½	50	6	$275 + 31$
23	4	18	2	
24	1	5	...	
25	7¼	31	...	
26	4¾	19	...	
April 16–26	98	577	151	$271{\cdot}2^\circ + 32{\cdot}9^\circ$ April 19–21.

The radiants from my own observations are :—

1885	April 18	... $260^\circ + 33^\circ$*		1879	April 20	... $272^\circ + 33^\circ$
1887	18	... $266 + 33$		1885	20	... $274 + 33$
1877	19	... $269 + 37$†		1887	20	... $271 + 33$
1884	19	... $269 + 33$		1893	20	... $272 + 33$
1885	19	... $268 + 33$		1878	21	... $272 + 32$
1887	19	... $269 + 31$		1893	21	... $273 + 34$
1878	20	... $273 + 32$		1878	22	... $275 + 31$

* Probably Herculids, and representing a stream quite distinct from the Lyrids.

† Certainly 4° N. of correct position. This radiant is omitted in deriving mean place in the previous table, and I have also quite disregarded the centre found at Bristol in 1873–4 when I had not acquired much practical experience in this line of work.

The radiants determined by other observers are:—

1839	Apr. 18	273° +45°*	58	Herrick.
1845–63	Apr. 19–20	282 +33	25	Greg.
1847–66	Apr. 15–31	277 +38	...	Heis.
1864	Apr. 19–20	277·5+34·6	23	A. S. Herschel.
1851–68	Apr. 18–29	277 +34	12	Heis.
1867	Apr. 19–20	278·2+34·5	16	Galle and Karlinski.
1869	Apr. 20	267 +35	7	Serpieri.
1871	Apr. 20	267 +35	17	A. S. Herschel.
1872	Apr. 19	275 +32	17	Lucas.
1874	Apr. 19–21	268 +33	7	Konkoly.
1877–78	Apr. 19–20	275 +35	24	Corder.
1879	Apr. 19	275 +37	13	Corder.
1879	Apr. 19–21	274 +34	10	Sawyer.
1882	Apr. 20	268 +37	26	Corder.
1893	Apr. 20–21	274·5+40·5†	47	Nijland and Bolt.
1893	Apr. 20–21	270·5+35·5	25	Corder.
1893	Apr. 20–21	270 +33	...	Farrington.
1893	Apr. 20–21	271 +35·5	...	Blakeley.
1895	Apr. 19	274 +34	...	Corder.
1895	Apr. 19	269 +37	9	Blakeley.
1895	Apr. 21	274 +36	9	Blakeley.
1896	Apr. 10–22	275 +38	6	A. S. Herschel.
1898	Apr. 21–22	273 +33	12	Besley.
1898	Apr. 12–23	270 +40†	5	A. S. Herschel.
1898	Apr. 20	275·5+31·5	22	Nijland.
1898	Apr. 21–24	276 +34	16	Nijland.

The mean of the 26 positions is 273°·3+35°·6.

A large number of valuable observations were made at the epoch of the Lyrids between the years about 1865 and 1874, when the interest in this branch of astronomy had received a great impetus from the discovery of the identity of certain cometary and meteoric orbits. In Austria Professor E. Weiss collected two volumes of observations from 1867 to 1874, and among these were many of the April meteors, though they had never been reduced to their radiant points. The observers were

* Probably 12° N. of the correct position.

† These may represent showers of Draconids, as the radiants are far N. of that of the Lyrids.

Möller, Palisa, Wittek, Schulhof, Oppolzer, Littrow, Strasser, Sauter, Niessl, Holetschek, Karlinski, and others, and the chief places of observation were at Vienna, Kremsmünster, and O-Gyalla.

The Italian Meteoric Association, under the direction of Schiaparelli and Denza, also amassed many thousands of observations in different months, and Zezioli's and Heis's catalogues contain a great many more. The total number of meteors registered by these observers during the special epoch April 16 to 25, in the years from 1865 to 1874, was approximately as follows :—

Weiss's Austrian observations (1867–74)	... ...	1,468 meteors.
Italian Meteoric Association (1869–72)	... ...	997 „
G. Zezioli at Bergamo (1867–70)	... ...	219 „
E. Heis at Münster (1865–74) ...	... ...	152 „
		2,836 „

I carefully examined all these paths for the purpose of tracing the position of the radiant on succeeding nights, and my results were as follow :—

Date. 1865–74.	Radiant. α	δ	Area.	Lyrids.	Meteors observed.
	°	°	°		
Apr. 16	270	+31*	6	5	35
17	267	+29	6	6	94
18	268	+33	7	7	66
19	268	+30	10	70	294
20	271	+34	15	214	915
21	273	+31	10	79	482
22	273	+32	15	48	396
23	275	+33	7	47	379
24	...		...	2	54
25	275	+31	8	9	121
Apr. 16–25	271·1	+31·6	...	487	2,836

The series of positions greatly favours the idea of a moving radiant, and I think there can be no doubt of its occurrence, though the exact rate of the displacement is not quite certain. Before April 20, both my observations and reductions prove that the radiant is certainly W. of R.A. 270°, while on April 20 and following nights it is as certainly E. of it. I do not, however, attach much importance to radiant points derived from a large

* This position, as well as those for April 17, 18, and 25, are not based upon a sufficient number of paths to be reliable, and little weight should be attached to them.

collection of miscellaneous observations, some of which will be sure to be erroneous, either owing to comparative inexperience on the part of some observers or other causes. On projecting a large number of combined observations of this character upon an 18-inch globe it is usually found that they form very indefinite, scattered radiants extending over areas of 10°, 15°, or even more; and that the centres cannot be assigned with any approach to accuracy. In any doubtful question as to the visible behaviour of meteoric streams, it is not therefore advisable to appeal to such data as capable of affording a final settlement. The selected materials of one observer of known accuracy and experience would be of much greater value, but unfortunately no single individual can furnish the mass of observations desirable. To acquire this, we must necessarily collect materials from many sources; and these, though sufficiently full, are apt to induce doubts as to their accuracy and prove the inexpediency of fully trusting them.

In endeavouring to find whether motion occurs in a radiant, only such meteors should be utilised as are well observed and situated near their radiants. If observers set themselves to accumulate observations of this kind, we should in a few years have the means of disposing of some vexed questions in this branch of observational astronomy. In the case of a shower like the Lyrids, which is very feebly visible except on the night of maximum, it is not likely that photography will render us any efficient help in the immediate future, and so we must continue to look to ordinary eye observation to clear up any doubtful points associated with this system.

I have selected from amongst my observations at Bristol a number of Lyrids which were well seen, and moved chiefly in declination or were near the radiant. Such paths are obviously very important in endeavours to solve the question as to a change of position in the radiant:—

Date.	h m	Mag.	Path. From.	Path. To.	Length.
1884 Apr. 19	11 24	1	271° +36°	271¾° + 36¾°	1°
1885 Apr. 19	12 19	4	266 +37⅓	264 +41	4
1885 Apr. 19	12 47	3	274½ + 39	278½ + 42⅓	4½
1887 Apr. 19	12 41	5	270⅓ + 15	271⅓ + 9	6
1887 Apr. 19	13 5	3	270 +69	270¾ + 79¾	10¾
1887 Apr. 19	13 13	♀	269 + 11	269 + 1	10
1895 Apr. 19	11 58	4	278½ + 34	283½ + 35½	4
1873 Apr. 20	11 13	2	264⅓ + 16	261⅓ + 9	9
1874 Apr. 20	12 35	3	273 − 5	273 − 10	5
1874 Apr. 20	12 56	2	270 + 4	269 − 3	7
1878 Apr. 20	9 16	3	264 +45	260 +49	5
1878 Apr. 20	9 30	3	262 +36	256 +38	5½

Date.	h m	Mag.	Path. From.	Path. To.	Length.
			° °	° °	°
1885 Apr. 20	13 20	4	275½ +27	275 +23	4
1885 Apr. 20	13 46	4	265 +53	262 +58	5½
1885 Apr. 20	14 12	4	270 +12½	269½ + 7	5½
1885 Apr. 20	14 24	4	261½ +21	258 +16¾	6
1885 Apr. 20	14 49	4	266 +20½	263 +16	5
1873 Apr. 21	10 22	3	273 +51	273 +61	10
1893 Apr. 21	12 8	♃	270 +44	268 +49½	6
1893 Apr. 21	12 39	4	268 +27¾	266½ +25½	2½
1878 Apr. 22	10 50	5	265 +61½	256 +71	11
1894 Apr. 22	9 59	2	260 +59	243 +72	15

Bristol, 1899 February 20.

Nebulæ observed at the Royal Observatory, Cape of Good Hope, in 1898.

(*Communicated by David Gill, C.B., F.R.S., &c., H.M. Astronomer.*)

The following observations were made by Mr. R. T. A. Innes with the 7-inch Merz equatorial :—

No.	R.A. 1860. h	m	s	Dec. 1860. °	′	
1	3	27	44	−52	23	Equal to $10^m.5$, round, 2′ diameter, near C.P.D. −52°, 414.
2	4	4	41	−45	53	Equal to $9^m.8$, round, 10″ diameter, near C.P.D. −45°, 403.
3	4	14	8	−60	33	Equal to $9^m.8$, round, 1′ diameter, brighter in middle.
4	5	39	0	−51	6	Equal to $9^m.7$, round, 10″ diameter, brighter in middle.
5	14	12	5	−59	56	Faint, small, elongated.

The above are supposed to be new.

h 2629=G. C. 834 The position for 1860 is about $4^h\ 12^m\ 44^s$ −55° 56′, the place in the N.G.C. being wrong. It is quite close to C.Z. IV., 419, mag. 8·5, reddish, and is 13′ N. *p*.

h 2630=G.C. 838, which is a double nebula, the smaller component being N. *f*.

h 3443. *h* calls this a cluster. It now looks like an irregular nebula surrounding two stars.

H. V. 39. Not seen; H. V. 40, which is near, and has exactly the same description, was well seen.

Royal Observatory, Cape of Good Hope:
1899 *January* 6.

Occultations Observed at the Royal Observatory, Cape of Good Hope, during the Lunar Eclipse, 1898 December 27.

(*Communicated by David Gill, C.B., F.R.S., &c., H.M. Astronomer.*)

A list of predictions was received from the Pulkowa Observatory. The observers, instruments, and their positions referred to the Cape Transit Circle, were :—

Observer.	Instrument.	δ Long. (s)	δ Lat. (″)	Alt.
H = S. S. Hough	7-in. Heliometer	−0·05	+2·01	About 40 ft.
L = J. Lunt	18-in. McClean Refractor	+ ·03	−3·43	
I = R. T. A. Innes	7-in. equatorial	+ ·12	−2·02	
V L = V. A. Löwinger	10-in. astrographic guiding telescope	− ·10	+4·42	

Position of T.C.

Long. $-1^h\ 13^m\ 54^s{\cdot}76$ δ Long. − = E. of T.C.

Lat. $-33°\ 56'\ 3''{\cdot}5$ δ Lat. − = S. of T.C.

The definition became very bad towards the end of the eclipse.

All the observers remark that the stars at disappearance seemed to enter on the Moon's disc.

Observations.

No.	Pulkowa List.	Name.	Mag.	Obsr.	Inst.	Phase.	Cape Sid. Time. h m s	Greenwich M.T. h m s	Remarks.
1	—	Anon = B.D. + 24°, 1298 + 30ˢ ±	9·7	L.	18-in.	D.	6 23 46·2	10 44 7·6	
2	33	B.D. + 24°, 1300	9·4	„	„	„	6 33 8·7	10 53 28·6	
„	„			I.	7	„	6 33 8·7	10 53 28·6	Very good.
„	„			V.L.	10	„	6 33 8·7	10 53 28·6	Faint.
3	25	B.D. + 24°, 1296	9·4	L.	18	R.	7 0 15·9	11 20 31·3	
„	„			V.L.	10	„	7 0 16·2	11 20 31·6	Good.
4	37	Arg. + 24°, 1303	9·1	L.	18	D.	7 1 47·7	11 22 2·9	
„	„			I.	7	„	7 1 47·7	11 22 2·9	Very good.
„	„			V.L.	10	„	7 [2] 48·9	11 22 4·1	Uncertain.
5	44	B.D. + 24°, 1306	9·2	L.	18	„	7 10 41·7	11 30 55·4	
„	„			I.	7	„	7 10 41·2	11 30 54·9	Good.
„	„			V.L.	10	„	7 10 40·9	11 30 54·6	Very fair.
6	—	Anon = B.D. + 24°, 1303 + 13ˢ − 0′·8	9·5	I.	7	„	7 10 49·7	11 31 3·4	Fair.

Pulkowa List.	Name.	Mag.	Obsr.	Inst.	Phase.	Cape Sid. Time. h	m	s	Greenwich M.T. h	m	s	Remarks.
42	B.D. + 24°, 1305	9·2	H.	Heliom.	„	7	16	36·0	11	36	48·8	Good.
„			L.	18-in.	„	7	16	36·9	11	36	49·7	
„			I.	7	„	7	16	37·3	11	36	50·1	Very good.
„			V.L.	10	„	7	16	36·9	11	36	49·7	Good.
–	B.D. + 24°, 1311	9·4	L.	18	„	7	25	55·7	11	46	6·9	Bad definition.
49	Arg. + 24°, 1310	9·2	„	„	„	7	26	53·2	11	47	4·3	
48	B.D. + 24°, 1309	9·0	H.	Heliom.	„	7	30	35·5	11	50	46·0	Very good.
„			L.	18-in.	„	7	30	35·4	11	50	45·9	
„			I.	7	„	7	30	35·4	11	50	45·9	Very good.
„			V.L.	10	„	7	30	35·5	11	50	46·0	Good.
47	B.D. + 24°, 1308	9·3	I.	7	„	7	31	58	11	52	8	Worthless.
„			V.L.	10	„	7	31	58·7	11	52	8·9	Fair, faint.
56	B.D. + 24°, 1313	9·2	L.	18	„	7	53	40·7	12	13	47·4	
„			I.	7	„	7	53	42	12	13	48	Worthless.
„			V.L.	10	„	7	53	41·2	12	13	47·9	Bad.

Royal Observatory, Cape of Good Hope:
1899 *January* 6.

On the Use of the Electric Light for the Artificial Star of a Zöllner Photometer. By W. de Sitter.

(*Communicated by David Gill, C.B., &c., H.M. Astronomer at the Cape.*)

During the last few months I have been engaged on photometric work in connection with an investigation of the systematic difference between visual and photographic magnitudes of stars in the Milky Way and near its poles.

The instrument used is the 6-inch equatorial, by Grubb, belonging to the Cape Observatory, to which an ordinary Zöllner photometer has been adapted in the way recommended by Zöllner (*Photometrische Untersuchungen*, Plates V. and VI.). As is fully explained in Zöllner's work, the paraffin lamp was automatically kept in a horizontal position while the telescope was being driven by the clockwork. On nights without wind the lamp performed very satisfactorily, and remained practically constant throughout the time of observation—usually from 1½ to 2 hours. But there are very few nights without wind at the Cape; and when the south-easter was blowing with its usual velocity of between 15 and 30 miles an hour, it was absolutely impossible to observe. This induced me to try to

replace the oil lamp by an electric lamp, the light of which would not be affected by the wind. As this is, so far as I know, the first trial ever made of the use of electric light in stellar photometry, I have thought it not without interest to publish my first experiences. Professor Muller writes (*Photometrie der Gestirne*, p. 252): "Eine grosse Gefahr ist das durch Wind und Luftzug hervorgebrachte Flackern der Flamme, welches namentlich das Beobachten im Freien wesentlich erschwert. Man kann sich zwar durch zweckmassige Construction der Blechcylinder, wie es bei den Potsdamer Photometern geschehen ist, theilweise dagegen schützen, es würde aber eine wesentliche Verbesserung des Apparates erzielt werden können, wenn es gelänge, anstatt der Petroleum-Lampe das elektrische Licht nutzbar zu machen . . . , und es kann nicht dringend genug zu Versuchen in dieser Richtung aufgefordert werden."

At first I simply put a 4-volt lamp in place of the oil lamp. The arrangement was then as follows:—The electric lamp was fixed to the brass bar which before carried the oil lamp, and was so adjusted that the light of a portion of the glowing filament fell through the small pinhole at the end of the photometer tube. The light after traversing the tube in the direction of its optical axis, and after passing through the various Nicol prisms, was reflected at an angle of 45° to form an image in the focus of the eyepiece. This image was a very sharp one, and more constant, as well as more star-like, than that formed by the oil lamp; and the equality of brightness of the real and artificial stars could be established quicker and with greater certainty than before.

But I found at the same time that the optical axis of the instrument did not coincide with its axis of rotation, and no adjustment could bring it to coincidence. In fact, there is no definite "axis of rotation." The rotating part of the instrument is not a circle resting on pivots, but a tube rotating inside another tube, and the mechanical fit is not so perfect (and, indeed, cannot be expected to be so in an instrument of this size and quality) as not to allow a certain irregular amount of play in the direction of the instantaneous axis of rotation. With the oil lamp, where a portion of a broad and practically uniformly illuminated surface is used, this introduced no appreciable error, but with the electric lamp the consequence was that in different positions of the rotating tube a different part, or a part of different size, of the glowing filament was used, so that the observations were not strictly comparable.

This error would perhaps be eliminated to a great extent by observing in the four quadrants; but a far better idea was suggested by Dr. Gill, viz. to have the lamp fixed to the end of the tube, so that it would rotate with it, and the relative positions of lamp, pinhole, and optical parts of the instrument would remain unchanged while the tube was rotated on its axis. This plan has been executed, and gives very good results.

To the end of the tube is clamped a piece of ebonite, in which a $3\frac{1}{2}$-volt lamp is fixed in an adjustable manner. The current is supplied from two accumulator cells in series, placed in the basement of the Observatory, and completely charged twice a week. These cells have a capacity of 130 ampère-hours, and yield a current having a practically constant E.M.F. of 4 volts.

From the cells the current is brought to the top of the pillar, and thence through free-hanging flexible wires to the lamp, so that there is nowhere any spring contact, which might introduce a difference of resistance in different positions of the instrument. No other lamps are fed from the same cells, and I find that the light is not only absolutely constant throughout the observations of one night, but generally even from night to night. A resistance coil has been introduced into the circuit, which enables me to regulate the brightness of the artificial star so as to avoid very small readings, for which the accuracy is not so great as between 10° and 50°. I can now make accurate observations of stars from the 1st to the 11th magnitude.

The weather has been extraordinarily bad this season, so that I had no time to make special observations for the purposes of this paper, and those now quoted simply form part of my regular observations. I observed every star in the four quadrants. The circle is divided from 0° to 180° in two directions, the reading 90° corresponding to the maximum brightness, and 0° and 180° to entire extinction. If there were no index error, and no systematic errors in the instrument, and no errors of observation, the readings in the four quadrants would be :—

$$\phi,\ 180^\circ - \phi,\ 180^\circ - \phi,\ \phi.$$

In reality the four readings are :—

$$\phi_1,\ 180^\circ - \phi_2,\ 180^\circ - \phi_3,\ \phi_4.$$

If we take the means of the readings in two adjacent quadrants, such as

$$\phi_{1.2} = \tfrac{1}{2}(\phi_1 + \phi_2) \qquad \phi_{1.4} = \tfrac{1}{2}(\phi_1 + \phi_4)$$
$$\phi_{3.4} = \tfrac{1}{2}(\phi_3 + \phi_4) \qquad \phi_{2.3} = \tfrac{1}{2}(\phi_2 + \phi_3),$$

the index error will be eliminated from these means. Now it is easy to see that any systematic error depending on the position of the rotating tube will have opposite effects on $\phi_{1.2}$ and $\phi_{3.4}$, and also on $\phi_{1.4}$ and $\phi_{2.3}$.

I therefore tabulated the differences $\phi_{1.2} - \phi_{3.4}$ and $\phi_{1.4} - \phi_{2.3}$ for a number of observations made on different nights in November and December of last year. The third and fourth columns of the following table give these differences, arranged in order of magnitude, of the mean of the four readings :—

Wt. Nr.	ϕ_0	$\phi_{1\cdot2}-\phi_{3\cdot4}$	$\phi_{1\cdot4}-\phi_{2\cdot3}$	Δ_1	Δ_2	Wt. Nr.	ϕ_0	$\phi_{1\cdot2}-\phi_{3\cdot4}$	$\phi_{1\cdot4}-\phi_{2\cdot3}$	Δ_1	Δ_2
	°	°	°	m	m		°	°	°	m	m
1	8·4	−0·3	+1·2	−·04	+·16	32	22·8	−4·9	+1·2	−·22	+·05
2	8·5	+1·0	−0·6	+·13	−·08	33	23·0	+0·6	+1·7	+·03	+·07
3	8·8	+1·5	+1·0	+·19	+·12	34	23·0	+2·0	−1·6	+·09	−·07
4	9·9	−0·5	+1·0	−·06	+·11	35	23·0	+2·0	+2·0	+·09	+·09
5	10·5	+0·6	+0·6	+·06	+·06	36	23·9	+2·2	+1·8	+·10	+·08
6	10·7	+1·0	+1·0	+·10	+·10	37	24·8	+2·5	+3·5	+·10	+·14
7	11·8	+0·5	−1·5	+·05	−·14	38	24·9	+0·9	+4·9	+·04	+·20
8	12·2	−0·5	−1·0	−·04	−·09	39	26·8	+6·5	0	+·26	0
9	13·2	−2·0	+0·5	−·16	+·04	40	29·8	−0·3	−0·4	−·01	−·01
10	15·8	+0·5	−0·5	+·03	−·03	41	30·4	+0·8	+2·3	+·03	+·08
11	15·8	−1·5	−0·5	−·10	−·03	42	30·5	−3·0	+4·0	−·10	+·13
12	15·8	+0·7	−1·3	+·05	−·08	43	33·4	−0·3	−2·3	−·01	−·07
13	17·1	−1·3	+1·3	−·08	+·08	44	34·1	+2·2	−0·2	+·07	−·01
14	18·0	+4·0	+1·0	+·24	+·06	45	34·8	−2·0	+2·0	−·05	+·05
15	18·2	+1·5	+1·5	+·09	+·09	46	36·0	+1·0	−0·4	+·02	−·01
16	18·2	+2·0	+4·5	+·12	+·27	47	41·4	−3·2	+4·7	−·06	+·09
17	18·5	+0·6	+1·0	+·04	+·06	48	42·5	+3·0	−1·0	+·06	−·02
18	18·6	+2·3	−0·3	+·14	−·02	49	48·0	+1·0	−2·0	+·02	−·04
19	19·0	−0·4	+2·0	−·02	+·12	50	50·8	−1·0	+6·8	−·02	+·10
20	19·2	+3·7	+1·6	+·19	+·08	51	53·5	+1·0	0	+·02	0
21	19·9	−1·8	+2·7	−·09	+·14	52	56·6	+2·8	+2·0	+·04	+·03
22	20·0	−1·0	+1·0	−·05	+·05	53	56·8	−1·5	−1·5	−·02	−·02
23	20·9	+0·7	−1·3	+·03	−·06	54	57·0	0	+3·0	0	+·04
24	20·9	−0·3	−0·4	−·02	−·02	55	58·2	+0·5	−0·5	+·01	−·01
25	21·3	+3·4	−3·5	+·16	−·17	56	58·8	−9·5	−3·5	−·11	−·04
26	21·6	+1·7	+0·5	+·08	+·02	57	70·2	−2·5	+1·5	−·01	+·01
27	22·0	+0·4	−3·0	+·02	−·13	58	70·6	−3·2	+4·3	−·02	+·02
28	22·5	−3·0	−2·6	−·13	−·11	59	76·8	+6·5	+0·5	+·03	+·02
29	22·6	+0·8	+1·2	+·04	+·05	60	82·0	+3·0	−3·0	+·01	−·01
30	22·6	+0·4	+0·8	+·02	+·04	61	82·4	−6·8	+6·7	−·03	+·03
31	22·7	+1·0	0	+·04	0						

The residuals $\phi_{1\cdot2}-\phi_{3\cdot4}$ and $\phi_{1\cdot4}-\phi_{2\cdot3}$ are very small, and it will be seen from the table that there is no regularity in the distribution of the positive and negative signs. We may safely conclude that *there is no appreciable systematic error in the instrument*, and that therefore the residuals are due to pure accidental errors of observation. On that supposition the difference $\phi_{1\cdot2}-\phi_{3\cdot4} = \frac{1}{2}(\epsilon_1+\epsilon_2) - \frac{1}{2}(\epsilon_3+\epsilon_4)$, where ϵ_1 is the error of ϕ_1, &c. These differences are therefore equivalent to errors of observation of one single pointing, or to twice the error of the mean of four pointings. Accordingly in the fifth and sixth columns I have given the numbers of the third and fourth columns divided by two and converted into magnitudes. Treating these as the residuals in the method of least squares, we find for the probable error of one observation, consisting of four pointings,

$$\pm 0^{\mathrm{m}}{\cdot}061.$$

The results given in this paper must only be considered as of a preliminary character. I intend to make a more thorough investigation of the instrument as soon as I can do so without seriously interfering with my regular observations.

Royal Observatory, Cape of Good Hope:
1899 January 3.

The Greenwich Meridian Observations of Polaris, 1836–1893, *with reference to Personality, the value of the Constant of Aberration, and the Star's parallax.* By W. G. Thackeray.

Some years ago, when discussing the observations of *Polaris* with the view of obtaining a value of the nutation constant, the results were likewise arranged with the purpose of determining the annual errors, but it was afterwards found that to include the two discussions in one paper made it too cumbersome, and so the latter part was omitted and the papers have lain dormant since. In turning out some old papers I have lately come upon them, and I append this short preface as an explanation why the right ascensions are reduced in the present form, and how it is that reference is made below to personal equations.

The right ascensions here dealt with are those extending from 1836 to 1893, and are divided into two periods. The first includes the observations made with the transit instrument from 1836 to 1850, and the second those made with the transit circle from 1851 to 1893. They have been all reduced to the year 1890·0 with the Struve-Peters value of precession, with the adopted value of the proper motion for 1890 of $+0^{s}.1550$, the value which was obtained from the discussion on the constant of nutation (*Mem. R.A.S.* vol. li.). They have further been corrected for personal equation to the adopted standard observer "C" by the quantities given in Table III. on p. 252 of the paper referred to above, a process which involved a considerable amount of work, and of which it seems desirable to preserve a record.

The values for any monthly mean are the combination of the results above and below pole, weighted according to the number of observations, and are given uncorrected for personality as well as corrected for personality.

The observations in January and February are mostly below-pole observations, those in July and August above-pole observations, but no observation is kept for place unless the azimuth error has been determined from the consecutive transits of one of the close circumpolars.

The observations have been taken direct from the "Greenwich Observations," and those for 1836–1850 have been corrected further to reduce them to the value of the aberration constant 20·445.

Monthly Means of Right Ascensions of Polaris reduced to 1890. (Adopted P.M. + 0s·1550 for 1890.)

I.—1836-1850. Transit Instrument. Uncorrected for Personality.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	s	s	s	s	s	s	s	s	s	s	s	s
α' =	33·22$_{18}$	33·09$_{23}$	33·62$_{44}$	32·31$_{167}$	31·88$_{145}$	31·49$_{131}$	30·80$_{[illegible]}$	30·44$_{72}$	30·24$_{130}$	32·30$_{150}$	32·51$_{167}$	32·54$_{[illegible]}$
α =	31·91	...	...	...	...	...	...	...	...	...	...	...
$\alpha'-\alpha$	+ 1·31	+ 1·18	+ 1·71	+ 0·40	− 0·03	− 0·42	− 1·11	− 1·47	− 1·67	+ 0·39	+ 0·60	+ 0·63

II.—1836-1850. Transit Instrument. Corrected for Personality.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
α'	32·27	32·13	32·72	31·56	30·95	30·80	30·04	29·89	29·59	31·47	31·64	31·76
α	31·13	...	...	...	...	...	...	...	...	...	...	...
$\alpha'-\alpha$	+ 1·14	+ 1·00	+ 1·59	+ 0·43	− 0·18	− 0·33	− 1·09	− 1·24	− 1·54	+ 0·34	+ 0·51	+ 0·63

III.—1851-1893. Transit Circle. Uncorrected for Personality.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
α'	31·90$_{123}$	31·82$_{92}$	31·45$_{200}$	31·20$_{193}$	30·66$_{217}$	30·74$_{[illegible]}$	30·97$_{135}$	31·18$_{164}$	30·72$_{179}$	31·07$_{[illegible]}$	31·24$_{[illegible]}$	31·51$_{216}$
α	31·10	...	...	...	...	...	...	...	...	...	...	...
$\alpha'-\alpha$	+ 0·80	+ 0·72	+ 0·35	+ 0·10	− 0·44	− 0·36	− 0·13	+ 0·08	− 0·38	− 0·03	+ 0·14	+ 0·41

IV.—1851-1893. Transit Circle. Corrected for Personality.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
α'	31·44	31·66	31·59	31·35	30·97	30·81	31·04	31·01	30·46	31·15	31·32	31·66
α	31·14	...	...	...	...	...	...	...	...	...	...	...
$\alpha'-\alpha$	+ 0·30	+ 0·52	+ 0·45	+ 0·21	− 0·17	− 0·33	− 0·10	− 0·13	− 0·68	+ 0·01	+ 0·18	+ 0·52

Comparing the results deduced with and without a correction for personality, it is apparent that such a correction is not justified by the little smoothing that is made, and seems to show that at Greenwich, where there are many observers engaged in observing, personality works little or no harm in the course of a year.

It is also clear that the results obtained with the transit circle are very superior to those obtained with the transit instrument. Therefore the transit-circle results alone are used in the rest of this paper, and those uncorrected for personality (III.).

Now let K be the correction to the adopted constant of aberration $20''\cdot445$, and let P be the star's parallax, α' the apparent and α the mean R.A.; then we have (Chauvenet, vol. i. pp. 633 and 645):—

$$\alpha' - \alpha = -\text{K} \sec \delta (\cos \odot \cos \epsilon \cos \alpha + \sin \odot \sin \alpha)$$
$$- \text{P} \sec \delta (\cos \odot \sin \alpha - \sin \odot \cos \epsilon \cos \alpha).$$

Then, assuming that no appreciable error will be introduced by taking the value of the Sun's longitude for the middle of each month—or, in other words, that the monthly means correspond fairly to the mean date of the month—and giving a weight of 1 to every hundred observations, we get the following series of equations:—

Right Ascensions.

K	P	s	W.
$-3\cdot1$ K	$-41\cdot5$ P	$= +0\cdot80$	1
$-24\cdot4$	$-33\cdot8$	$= +0\cdot72$	1
$-37\cdot2$	$-18\cdot5$	$= +0\cdot35$	3
$-41\cdot4$	$+3\cdot0$	$= +0\cdot10$	5
$-34\cdot8$	$+22\cdot8$	$= -0\cdot44$	3
$-18\cdot8$	$+37\cdot0$	$= -0\cdot36$	3
$+1\cdot2$	$+41\cdot6$	$= -0\cdot13$	1
$+21\cdot6$	$+35\cdot5$	$= +0\cdot08$	1
$+36\cdot5$	$+19\cdot9$	$= -0\cdot38$	5
$+41\cdot5$	$-0\cdot8$	$= -0\cdot03$	5
$+35\cdot3$	$-21\cdot9$	$= +0\cdot14$	4
$+19\cdot2$	$-36\cdot8$	$= +0\cdot41$	2

$$39179\ \text{K} - 2295\ \text{P} = -\overset{s}{47\cdot31}$$
$$-2295\ \text{K} + 19685\ \text{P} = -224\cdot91$$

whence

$$\text{P} = -\overset{s}{0\cdot012}$$
$$\text{K} = -0\cdot002$$

which give

Aberration.	Parallax.
$20''\cdot42$	$-0''\cdot17$

The value of the parallax from the right ascensions is thus negative, showing that the observations are affected by some other annual term.

We now come to the declinations.

The observations are those made with the transit circle from 1851 to 1893, and thus comprise six complete periods of Chandler's latitude variation. The observations are all reduced on one system, that in present use, and have been corrected for the newly determined values of division errors, which are, generally speaking, for *Polaris* 1851–1877 $''\cdot00$, and for 1878 1893 $+0''\cdot25$, *Polaris* S.P. 1851–1856 $+0''\cdot10$, 1857–1877 $-0''\cdot10$, and for 1878–1893 $''\cdot00$. The observations from 1868 to 1876 have also been corrected for the wear in the microscope micrometer screws.

The observations are all reduced to 1890 with an adopted proper motion of $-0''\cdot005$.

Monthly Means of Declinations of Polaris 1851–1893 *reduced to* 1890. (*Adopted P.M.* $-0''\cdot005$.)

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
$\delta' =$	$18''\cdot65$	$18''\cdot45$	$18''\cdot26$	$18''\cdot09$	$18''\cdot15$	$18''\cdot25$	$18''\cdot68$	$18''\cdot79$	$18''\cdot63$	$18''\cdot54$	$18''\cdot49$	$18''\cdot57$
$\delta -$	$18\cdot42$	.	..	...	...	...	...	...	...	...	...	...
	$+0\cdot23$	$+0\cdot03$	$-0\cdot16$	$-0\cdot33$	$-0\cdot27$	$-0\cdot17$	$+0\cdot26$	$+0\cdot37$	$+0\cdot21$	$+0\cdot12$	$+0\cdot07$	$+0\cdot15$

Let K be the correction to the adopted constant of aberration, P the star's parallax, δ' and δ the apparent and mean declination, then by Chauvenet, vol. i. p. 633,

$$\delta'-\delta = -K\cos\odot(\sin\epsilon\cos\delta-\cos\epsilon\sin\delta\sin a)-K\sin\odot\sin\delta\cos a-P\sin\odot(\cos\epsilon\sin\delta\sin a-\sin\epsilon\cos\delta)-P\cos\odot\sin\delta\cos a.$$

Then, assuming the value of the Sun's longitude as before, we get the following series of equations :—

Declinations.			W.	C—O	$+''17 \sin 2\odot$
+1·00 K	−0·13 P	= +0″·23	3	−0·22	−0″·13
+0·77	−0·63	= +0·02	3	−0·14	−0·16
+0·38	−0·91	= −0·19	5	·00	−0·03
−0·13	−0·98	= −0·31	7	+0·07	+0·13
−0·60	−0·79	= −0·27	7	+0·07	+0·16
−0·91	−0·37	= −0·17	6	+0·05	+0·03
−0·98	+0·09	= +0·26	4	−0·28	−0·12
−0·81	+0·57	= +0·37	4	−0·27	−0·16
−0·42	+0·90	= +0·21	5	−0·02	−0·04
+0·08	+0·99	= +0·11	6	+0·13	+0·12
+0·57	+0·81	= +0·07	6	+0·13	+0·16
+0·90	+0·40	= +0·15	5	−0·07	+0·04

$$23{\cdot}69\,K + 3{\cdot}56\,P = +1''{\cdot}71$$
$$+3{\cdot}56\,K + 34{\cdot}44\,P = +8{\cdot}13,$$

whence

$$P = +0''{\cdot}23$$
$$K = +0{\cdot}037,$$

which give

Aberration.	Parallax.
20″·49	+0″·23.

The residuals C—O appear to demonstrate the existence of a six months' term, which can be fairly expressed by the formula $+''{\cdot}17 \sin 2\odot$, and which appears to be consistent and persistent throughout the period, for it is found that the values of the coefficient for the two periods 1851–1868 and 1869–1893 are +″·13 and +″·24 respectively. It will, however, be found that it does not affect the determined values of either the aberration or the parallax. In order to trace, if possible, the origin of this period the observations above and below pole have been separated, and the results given by Polaris and Polaris S.P. have both been discussed for the values of the aberration constant and for parallax. It will be seen that the aberration constant now differs considerably for the two determinations, the value from the above pole observations being the larger.

Monthly variations in declination of Polaris and Polaris S.P., 1851–1893.

	Polaris.			Polaris S.P.			C−O	
	δ′−δ	No. of Obs.	Wt.	δ′−δ	No. of Obs.	Wt.	Polaris.	Polaris S.P.
January	+0″·28	278	5	+0″·17	64	1	−0″·27	−0″·16
February	+0·02	184	3	−0·07	69	1	−0·14	−0·05
March	−0·17	232	4	−0·28	235	4	−0·04	+0·07
April	−0·49	247	4	−0·20	435	7	+0·23	−0·06
May	−0·27	238	4	−0·32	489	8	+0·04	+0·09
June	−0·32	203	3	−0·13	400	7	+0·19	·00
July	−0·01	111	2	+0·35	274	5	−0·01	−0·37
August	·00	94	2	+0·53	264	4	+0·11	−0·42
September	+0·01	300	5	+0·39	236	4	+0·20	−0·18
October	+0·14	362	5	+0·17	267	4	+0·11	+0·08
November	+0·19	343	6	+0·05	237	4	+0·04	+0·18
December	+0·35	308	5	−0·13	163	3	−0·21	+0·27
Mean δ	18·47	2900	...	18·41	3125			

Equating as before, we get :—

	Aberration.	Parallax.
Polaris	20″·67	+0″·21
Polaris S.P.	20·30	+0·30
Mean	20·49	+0·26

The values of C−O in the table above are given for the mean values of the aberration and parallax. An inspection will show that the six months' term has apparently disappeared, and that the residuals for Polaris S.P. are large.

In the course of a year the observations of Polaris and Polaris S.P. between them are fairly distributed throughout the day and night, as will be seen from the following diagram, where the dark line represents the time when the observations are made between sunset and sunrise, and the absence of the line the time when they are made between sunrise and sunset :—

Polaris

Polaris S.P.

Rearranging the observations of Polaris and Polaris S.P. indiscriminately to represent daylight and night observations in

accordance with this diagram, and giving each month the same weights as above, we get :—

	Aberration.	Parallax.
Daylight	20″·65	+0″·21
Night	20·36	+0·34

It must be borne in mind that the observations of Polaris are peculiarly liable to anything like diurnal periods in the zenith-point corrections.

Note on Diurnal Variations of the nadir and level of the Transit Circle at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

Suspicion having been aroused as to the possibility of a variation in nadir of the transit circle depending on the hour of the day, observations of the nadir and level have been made at Greenwich three times a day on all fine days since the middle of 1895—once in the early part of the day, again as soon as observations were commenced in the evening, and finally at the end of the evening's work. These observations have been here arranged in three groups, each extending to six hours, viz. 21^h-3^h, 3^h-9^h, 9^h-15^h (astronomical reckoning), representing roughly the observations made about midday, about sunset, and at the end of the evening's work. Taking the results of the middle group 3^h-9^h as zero, the following table exhibits for each month the corrections to this group (that is, to the nadir observation made about sunset) derived from the observations made about midday and midnight :—

DIURNAL VARIATIONS OF THE NADIR.

Corrections to the observations of the nadir about 6 P.M. deduced from the observations made about midday and midnight.

Month.	1895		1896.		1897.		1898.		Means.		General Mean.	No. of Obs.
	21^h to 3^h.	9^h to 15^h.	21^h to 3^h.	9^h to 15^h.	21^h to 3^h.	9^h to 15^h.	21^h to 3^h.	9^h to 15^h.	21^h to 3^h.	9^h to 15^h.		
	"	"	"	"	"	"	"	"	"	"	"	
Jan.	...	...	$+\cdot58_{2}$	$-\cdot51_{2}$	$-\cdot17_{2}$	$-\cdot10_{2}$	$+\cdot03_{2}$	$+\cdot28_{2}$	$+\cdot04$	$-\cdot07$	$-\cdot02$	20
Feb.	...	...	$-\cdot46_{3}$	$-\cdot31_{2}$	$\cdot12_{4}$	$+\cdot19_{4}$	$+\cdot11_{7}$	$+\cdot18_{7}$	$-\cdot08$	$+\cdot08$	$\cdot00$	28
Mar.	...	...	$+\cdot13_{6}$	$+\cdot01_{4}$	$+\cdot32_{6}$	$+\cdot38_{6}$	$-\cdot10_{4}$	$-\cdot03_{1}$	$+\cdot17$	$+\cdot17$	$+\cdot17$	36
Apr.	...	...	$-\cdot05_{5}$	$+\cdot15_{4}$	$+\cdot24_{9}$	$+\cdot31_{9}$	$+\cdot03_{11}$	$+\cdot12_{11}$	$+\cdot07$	$+\cdot19$	$+\cdot13$	56
May	...	...	$+\cdot64_{9}$	$+\cdot35_{9}$	$+\cdot24_{12}$	$+\cdot29_{12}$	$-\cdot04_{8}$	$+\cdot13_{8}$	$+\cdot29$	$+\cdot26$	$+\cdot27$	58
June	...	...	$+\cdot18_{12}$	$+\cdot12_{12}$	$+\cdot15_{8}$	$+\cdot05_{8}$	$+\cdot21_{8}$	$-\cdot16_{8}$	$+\cdot18$	$+\cdot04$	$+\cdot11$	54
July	$-\cdot07_{7}$	$-\cdot18_{7}$	$+\cdot06_{8}$	$+\cdot22_{8}$	$+\cdot14_{13}$	$+\cdot16_{13}$	$-\cdot10_{7}$	$\cdot00_{7}$	$+\cdot04$	$+\cdot15$	$+\cdot10$	74
Aug.	$+\cdot52_{12}$	$+\cdot41_{17}$	$+\cdot12_{9}$	$-\cdot06_{9}$	$-\cdot20_{13}$	$-\cdot25_{13}$	$+\cdot26_{18}$	$+\cdot21_{18}$	$+\cdot16$	$+\cdot07$	$+\cdot11$	102
Sept.	$+\cdot12_{11}$	$+\cdot09_{11}$	$+\cdot13_{8}$	$+\cdot13_{8}$	$+\cdot16_{7}$	$+\cdot17_{7}$	$+\cdot43_{17}$	$+\cdot13_{17}$	$+\cdot25$	$+\cdot13$	$+\cdot19$	82
Oct.	$+\cdot19_{9}$	$+\cdot26_{9}$	$+\cdot35_{10}$	$+\cdot34_{10}$	$+\cdot08_{13}$	$+\cdot33_{13}$	$-\cdot03_{9}$	$+\cdot28_{9}$	$+\cdot15$	$+\cdot31$	$+\cdot23$	80
Nov.	$+\cdot41_{9}$	$+\cdot36_{9}$	$+\cdot26_{7}$	$+\cdot37_{7}$	$+\cdot49_{4}$	$+\cdot64_{4}$	$+\cdot44_{6}$	$+\cdot23_{6}$	$+\cdot39$	$+\cdot36$	$+\cdot37$	56
Dec.	$+\cdot45_{6}$	$+\cdot33_{6}$	$+\cdot21_{3}$	$+\cdot49_{3}$	$+\cdot17_{9}$	$+\cdot20_{9}$	$+\cdot11_{9}$	$-\cdot13_{9}$	$+\cdot22$	$+\cdot15$	$+\cdot18$	54
Means	$+\cdot28_{51}$	$+\cdot27_{64}$	$+\cdot20_{81}$	$+\cdot16_{81}$	$+\cdot11_{100}$	$+\cdot17_{100}$	$+\cdot16_{101}$	$+\cdot11_{101}$	$+\cdot17$	$+\cdot17$	$+\cdot17$	700

An inspection of this table will show that there appears to be a semi-diurnal variation in the nadir, whose amplitude varies in the different months. The groups into which the observations are divided are too long to give very reliable details, but the observations are not sufficiently numerous to warrant smaller subdivisions.

As it is manifestly of interest to see if the observations of level show any similar variations, the level errors have been collected together for those days on which three observations have been made within the times specified, by the arrangement of groups referred to above, and they are here given in an exactly similar form to those of the nadir:—

DIURNAL VARIATIONS OF THE LEVEL ERROR.

Corrections to the values of the level error found about 6 P.M. from the observations made about midday and midnight.

Month.	1895.		1896.		1897.		1898.		Means.		General Mean.	No. of Obs.
	21^h to 3^h.	9^h to 15^h.	21^h to 3^h.	9^h to 15^h.	21^h to 3^h.	9^h to 15^h.	21^h to 3^h.	9^h to 15^h.	21^h to 3^h.	9^h to 15^h.		
	"	"	"	"	"	"	"	"	"	"	"	
Jan.	...	...	$-{\cdot}22_{7}$	${\cdot}00_{3}$	$-{\cdot}15_{4}$	$-{\cdot}23_{6}$	$+{\cdot}11_{4}$	$+{\cdot}20_{4}$	$-{\cdot}06$	$-{\cdot}01$	$-{\cdot}03$	20
Feb.	...	...	$+{\cdot}13_{2}$	$+{\cdot}16_{2}$	$+{\cdot}22_{4}$	$+{\cdot}28_{4}$	$+{\cdot}34_{6}$	$+{\cdot}19_{6}$	$+{\cdot}27$	$+{\cdot}21$	$+{\cdot}23$	30
Mar.	...	...	$+{\cdot}25_{6}$	$+{\cdot}23_{6}$	$+{\cdot}03_{10}$	$-{\cdot}06_{10}$	$+{\cdot}31_{7}$	$+{\cdot}31_{7}$	$+{\cdot}17$	$+{\cdot}13$	$+{\cdot}15$	46
Apr.	...	...	$+{\cdot}53_{6}$	$+{\cdot}38_{6}$	$+{\cdot}28_{10}$	$+{\cdot}16_{10}$	$+{\cdot}21_{12}$	$+{\cdot}22_{11}$	$+{\cdot}32$	$+{\cdot}24$	$+{\cdot}28$	58
May	...	...	$+{\cdot}36_{6}$	$+{\cdot}37_{6}$	$+{\cdot}29_{14}$	$+{\cdot}10_{14}$	$+{\cdot}30_{9}$	$+{\cdot}11_{9}$	$+{\cdot}31$	$+{\cdot}17$	$+{\cdot}24$	60
June	...	...	$+{\cdot}51_{12}$	$+{\cdot}29_{12}$	$+{\cdot}34_{6}$	$+{\cdot}37_{6}$	$+{\cdot}33_{5}$	$+{\cdot}36_{5}$	$+{\cdot}42$	$+{\cdot}33$	$+{\cdot}38$	50
July	$+{\cdot}13_{7}$	$+{\cdot}17_{7}$	$+{\cdot}38_{9}$	$+{\cdot}06_{9}$	$+{\cdot}06_{10}$	$+{\cdot}11_{10}$	$+{\cdot}49_{6}$	$+{\cdot}04_{6}$	$+{\cdot}21$	$+{\cdot}10$	$+{\cdot}16$	68
Aug.	$+{\cdot}26_{12}$	$+{\cdot}15_{12}$	$+{\cdot}36_{10}$	$+{\cdot}26_{10}$	$+{\cdot}32_{14}$	$+{\cdot}06_{14}$	$+{\cdot}07_{14}$	$+{\cdot}12_{14}$	$+{\cdot}25$	$+{\cdot}14$	$+{\cdot}20$	100
Sept.	$+{\cdot}17_{11}$	$+{\cdot}15_{11}$	$+{\cdot}16_{6}$	$+{\cdot}29_{6}$	$+{\cdot}22_{16}$	$+{\cdot}16_{16}$	$+{\cdot}83_{17}$	$+{\cdot}43_{17}$	$+{\cdot}44$	$+{\cdot}28$	$+{\cdot}36$	88
Oct.	$+{\cdot}13_{8}$	$+{\cdot}20_{8}$	$+{\cdot}18_{8}$	$+{\cdot}20_{8}$	$+{\cdot}26_{13}$	$+{\cdot}31_{13}$	$+{\cdot}17_{11}$	$+{\cdot}15_{11}$	$+{\cdot}18$	$+{\cdot}22$	$+{\cdot}20$	84
Nov.	$-{\cdot}06_{9}$	$-{\cdot}09_{9}$	$+{\cdot}07_{7}$	$+{\cdot}08_{7}$	$+{\cdot}16_{4}$	$+{\cdot}37_{4}$	$+{\cdot}32_{5}$	$+{\cdot}20_{5}$	$+{\cdot}08$	$+{\cdot}09$	$+{\cdot}09$	50
Dec.	$+{\cdot}08_{6}$	$+{\cdot}39_{6}$	...	...	$+{\cdot}22_{9}$	$-{\cdot}04_{9}$	$+{\cdot}18_{9}$	$+{\cdot}24_{9}$	$+{\cdot}17$	$+{\cdot}17$	$+{\cdot}17$	48
Means	$+{\cdot}13_{41}$	$+{\cdot}16_{44}$	$+{\cdot}31_{79}$	$+{\cdot}24_{79}$	$+{\cdot}20_{114}$	$+{\cdot}13_{114}$	$+{\cdot}33_{104}$	$+{\cdot}23_{104}$	$+{\cdot}25$	$+{\cdot}18$	$+{\cdot}22$	702

This table shows that there is a semi-diurnal variation in the level as well as in the nadir. It would follow from this that stars 6^h apart in right ascension would be liable to give the value of the azimuth error systematically different.

Photographs of Comets, and of the Milky Way. By E. E. Barnard.

I have, at various times, sent a number of photographs of the Milky Way, comets, &c., &c., to the Royal Astronomical Society, but these were not accompanied by any descriptions of the pictures.

It was my intention to describe in detail each one of these pictures to facilitate their study, and to put on record some of the more important features shown on the plates; for various reasons I was unable to do this when sending the pictures. I take the opportunity now, while sending a number of lantern slides from these and other pictures, to partially remedy the omission.

The Royal Astronomical Society has published some reproductions and lantern slides from the star and comet pictures previously sent. The present descriptions will also cover some of these, and for easy reference I shall indicate such pictures by the additional designation, *R.A S.*, No. —, the number being that given in the "List of Reproductions of Celestial Photographs published by the Royal Astronomical Society" (see page 210). At best, these descriptions will cover only a few of the total lot of pictures sent by me to the R.A.S. at various times.

A few brief remarks of an historical nature may perhaps be important before entering on the descriptions.

While connected with the Lick Observatory, a series of photographs was made of all the different portions of the Milky Way which were visible from that latitude. This work was begun in the spring of 1889. The instrument employed, as is well known, was a 6-inch portrait lens of 31 inches focus, which bore the name of Willard, and the date 1859, and for this reason I have called it the "Willard lens" in all my work. This lens was used in the early days of wet plate photography for portrait work in a San Francisco photograph gallery. In the early times it was necessary to use a large aperture to lessen the duration of exposure in taking portraits; but after the invention of the quick dry plates, such a large lens became unnecessary, and this one was discarded for smaller and more convenient lenses.

Upon experimenting with this large lens, I found, on account of its wide field and great light-grasping power, that it was specially suited for the photography of the Milky Way, comets, &c. It was attached to a wooden camera box, and was first used by strapping it to the tube of the 6-inch equatorial. Latterly it was placed on an ordinary equatorial mounting, which did not permit continuous exposures to be carried across the meridian.

Besides the pictures of the Milky Way and nebulæ, a number of photographs were secured of Swift's Comet of 1892, Holmes's

Comet of 1892, Brooks's Comet of 1893, and Gale's Comet of 1894.

The photographs of the Milky Way made with the Willard lens were the first to show its cloud forms and general structure. They opened up the means for a thorough study of the Milky Way such as had not before existed. Indeed, it is safe to say that little or nothing was known of the structural peculiarities of the Milky Way before these photographs were made. Visual means, on account of the smallness of the field of view, could give only the vaguest and most uncertain ideas of its wonderful structure. But the extended views given us by the wide field of the rapid portrait lens, place before us the Milky Way in all its sublimity. Every rift and chasm is shown ; the cloud forms, the great nebulous regions, and the singular alignments of stars, are all faithfully portrayed for permanent study. It is through the study of these details that we shall ultimately know something definite concerning the universe of stars in which our own Sun is placed.

For the study of the phenomena of the tails of comets, the portrait lens has shown itself most admirably suited. It has added an interest to the physical study of these bodies that did not exist previously ; for the most interesting of the phenomena shown by comets must always escape the visual observer and pass unknown, without the aid of the portrait lens and the photographic plate. Unlike the planets, the comets often traverse the entire solar system. They are, therefore, our only means of exploring the regions between the planetary orbits. Instead of ponderous bodies like the planets, they are but flimsy creations of enormous dimensions. They are thus likely to be easily subject to disturbances in their forms that would produce no perceptible effect on their motions. What these influences may be we do not know ; probably swarms or streams of meteors, which we know do exist in space, or possibly some other cosmical matter yet unknown. Such objects might be (and possibly have been) revealed to us by their effect upon the form of the comet's tail as it sweeps through space.

Swift's Comet of 1892.

This was the first comet to show to the photographic plate the extraordinary changes to which these bodies are subject. Indeed, if it had not been for the photographic plate we should have known nothing of the extraordinary changes that occurred in this comet and several that have since appeared.

Photographs taken April 4 and 5 showed that very rapid changes were taking place in the comet ; these changes seemed to culminate in the extraordinury phenomenon of April 7.

A study of the various photographs of this comet would seem to show that the observed phenomena can readily be explained by

disturbances in the nucleus, and by the ejection of the matter composing the head in a direction away from the Sun.

1892 April 6^d 15^h 30^m—16^h 35^m. (Lantern slide.)

In this photograph there is no resemblance to the appearance of the comet on preceding dates.

The tail consists of two broad streams, the northern of which is very bright, and the southern faint. The two streams merge together near the head, and at this point there is a quick bend in its southern side. A great deal of detail is shown in the brighter component in the form of bright streaks and patches. Fine threads or short "whisker tails" extend back from the head at considerable angles to the main tail. There are some indications present also of the remarkable disturbance which followed some twenty-four hours later.

1892 April 7^d 15^h 45^m—16^h 35^m. (Lantern slide.)
R.A.S., No. 10.

This picture shows a remarkable development in the tail at the back of the head, which might be taken for a secondary comet with a system of tails of its own. This singular development appears on one of a series of thin strands into which the tail has separated. This particular strand is the largest and brightest and somewhat curved, and becomes suddenly thinner near the head. These phenomena are very beautifully shown on the photograph. The large mass or secondary comet was doubtless thrown off from the nucleus or head some time during the preceding twenty-four hours, and must have had a very considerable velocity.

1892 April 24^d 13^h 50^m—16^h 10^m. (Lantern slide.)

This is a generally characteristic view of the comet. The tail partially separates into a number of streams, and on the north side is very sharply defined by what appears to be a thin black rift; if this edge of the tail is continued to the comet, it will pass south of the centre of the head, and consequently does not appear due to a force at that moment seated in the nucleus. The south portion of the inner bright tail is irregular near the head, and in this resembles some of the peculiarities of the tail of April 6.

1892 April 26^d 13^h 45^m—16^h 10^m. (Lantern slide.)

The multiple structure of the tail is well shown. It appears to be made up of a number of bright strands which centre in the head.

Holmes's Comet and the Andromeda Nebula.

1892 November 21^d 8^h 55^m—10^h 10^m. (Lantern slide.)

The apparent motion of the comet was so slow that it was possible to obtain a sharp picture of both comet and nebula—a circumstance that is not likely to happen again soon.

The short exposure (75^m) for this picture shows splendidly the rapid action of the portrait lens. Nearly everything that is usually shown in long exposure photographs of the nebula is brought out very clearly with this comparatively short exposure. There is a bright speck in the comet near its preceding edge; this, however, was a fixed star, and not the nucleus, as might be supposed.

An earlier picture, November 10, shows the comet round and sharply defined like a planetary nebula, with a symmetrical nebulous atmosphere surrounding it for some distance. That photograph also shows an irregular nebulous appendage about a degree to the south-east of the comet and attached to it by a hazy connection. This particular photograph (a copy of which is in the possession of the *R.A.S.*, No. 17) is very suggestive, taken in connection with the collision theory offered by several astronomers to account for the sudden appearance of this body. It was suggested that the object was not a comet in the ordinary sense of the word, but the result of a collision of two asteroids, for the orbit seemed to lie in the asteroid zone. The failure to see the comet previous to its sudden apparition near the Andromeda Nebula, its uncometary appearance, its peculiar freaks, and final utter disappearance from the heavens, connected with the nebulous appendage shown in the photograph of November 10, would strongly suggest that the object was not a comet at all, but more probably a result of some celestial accident. I think there is no question but this "comet" will never be seen again, and doubtless before now it has ceased to exist as an individual body.

I do not wish it to be understood that I endorse the theory that the apparition of this object was due to the collision of two asteroids. It may have been due to something besides the collision of one asteroid with another. We know too little about what may really exist in that region besides the individual asteroids themselves. Certainly many of the phenomena presented by this body were entirely uncometary. In some of the stages of its existence, however, its appearance was perfectly cometary. I have a photograph of it on December 10, when its diameter was about ½ degree. It was a well developed comet then, with a nucleus and central brightness and a diffusion of the head away from the Sun. This is a beautiful picture, and the stars shine through the comet everywhere. A month later, after it had become excessively faint and diffused, it suddenly (1893 January 16) assumed the form of a bright nebulous star, and again underwent a process of expanding and diffusion, and finally disappeared.

1893 *Brooks's Comet.*

Photographically this was the most remarkable comet that has yet appeared. It is scarcely necessary to say that had it not been for the photographs obtained of it with the Willard lens, we should have known nothing whatever of the extraordinary phenomena which were presented by this body, and which I am convinced will some day be seen to have a bearing upon a problem outside of that of the comet itself and of the highest importance to astronomy.

I have selected five of the photographs of this comet for description, four of which bear directly upon the subject just mentioned.

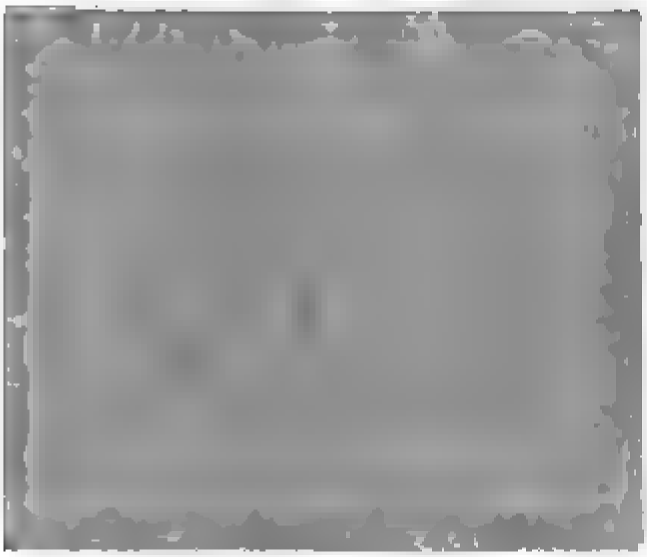
1893 October 20^{d} 16^{h} 35^{m}—17^{h} 10^{m}. (Lantern slide.) *R.A.S.*, No. 14.

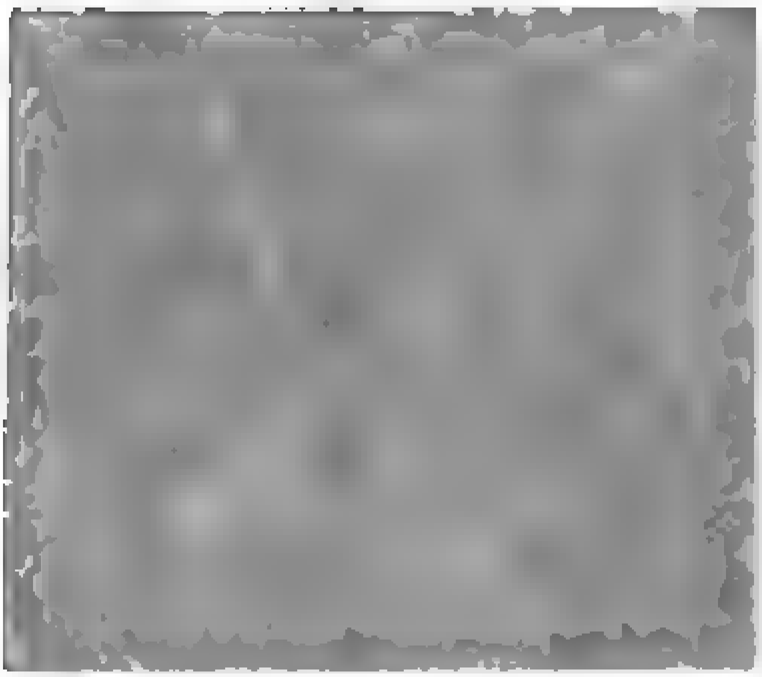
This picture shows the tail straight, but gradually widening, and diffused more or less to the north. From the northern side of the head a short diffused tail stretches out for half a degree or more, at an angle of some thirty degrees to the main tail. The apparent motion of the comet was in a direction nearly perpendicular to the length of the tail towards the north-east, and this is the direction from which the disturbance seemed to come in the later pictures.

1893 October 21^{d} 16^{h} 37^{m}—17^{h} 12^{m}. (Lantern slide.) *R.A.S.*, No. 9.

There is an utter transformation of the comet in this picture. The tail is larger and brighter and very much distorted, as if it had encountered some resistance in its sweep through space. This disturbance seems to have disrupted the north-east edge of the tail. The small side tail has apparently been swept away, while the more distant portion of the main tail is streaming in a very irregular manner. The entire picture is highly suggestive of an encounter with some sort of resistance. Is it possible the tail passed through a stream of meteors such as we know exist in space? Whatever the cause may have been, the appearance of the tail utterly excludes the idea of the phenomenon being due to irregular emission of the matter from the nucleus—an explanation quite satisfactory in the case of Swift's Comet.

In passing, this particular photograph seems to explain at least one of the ancient descriptions of a comet, viz., "a torch appeared in the heavens." The comet, as shown in the photograph, is sufficiently suggestive of a torch streaming irregularly in the wind.





[illegible]

[illegible]

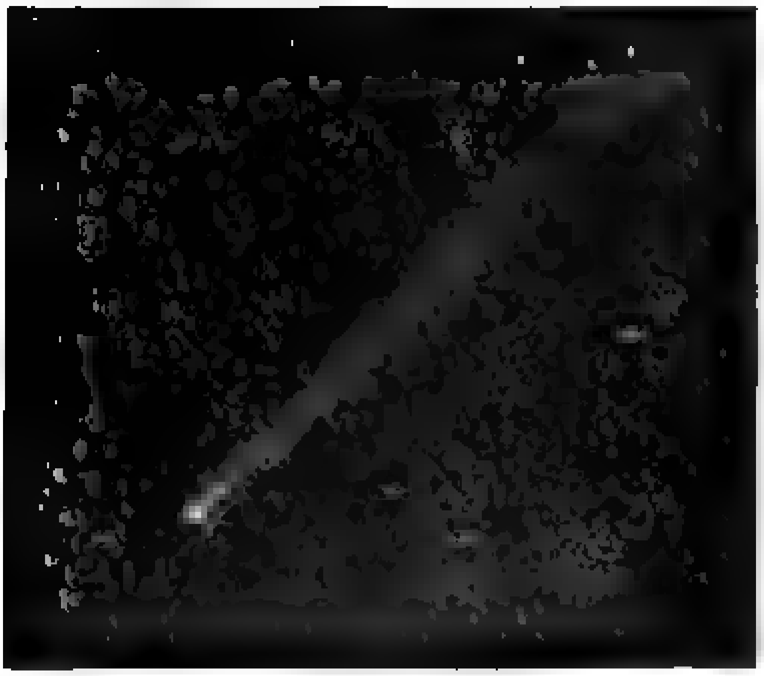
[illegible] from which the disturbance seemed to come in the [illegible] pictures.

[illegible] (Lantern slide.)

[illegible] of the [illegible] in this picture [illegible] distorted, as if it had encountered some resistance [illegible] through space. The disturbance [illegible] north-east edge of the tail. [illegible] been swept away, while [illegible] streaming in a very irregular [illegible] highly suggestive of [illegible] while the tail passed through a stream of meteors [illegible] exist in space. Whatever the [illegible] appearance of the [illegible] excludes the [illegible] due to [illegible] emission [illegible] matter [illegible] an explanation [illegible] satisfactory [illegible]

[illegible] this [illegible] seems to explain [illegible] in the [illegible]

Brooks's Comet, 1893 November 2^d 16^h 10^m—17^h 25^m.



Brooks's Comet, 1893 November 11^d 15^h 58^m—17^h 35^m.

1893 October 22^d 16^h 30^m—17^h 12^m. (Lantern slide.)
R.A.S., No. 13.

The tail appears a total wreck in this photograph, and is still more suggestive of a disaster. It is very badly broken, and on the south-west side hangs in irregular cloud-like masses. Near the extremity a large gap exists in the tail, as if something had gone through it from the north-east, and a large mass is torn oft beyond this break and seems to be drifting independent of the comet. Several of the other photographs which I obtained of this object show similar masses disconnected from the tail.

1893 November 2^d 16^h 10^m—17^h 25^m. (Lantern slide.)
(Plate 5.)

This is, perhaps, the next most remarkable picture of this comet, and shows that it was still in a disturbing region. The tail looks as if it were beating against a resisting force, and it seems to be encountered—as in all the photographs—on the advancing side of the tail. The motion of the comet was perpendicular to the tail towards the east, and, as will be seen, this is the direction from which the resistance seems to come. At one point the tail is nearly discontinuous, and at the end it is turned off abruptly nearly at right angles, as if at that point a greater current of resistance was encountered.

One or two other photographs show the tail badly broken and drifting in irregular fragments through space. These four pictures, however, are sufficiently characteristic of the phenomena shown by this comet to strongly suggest the idea that the tail must have encountered some form of resistance in its journey around the Sun, in this part of the heavens, on or about October 21, and at other times subsequent.

1893 November 11^d 15^h 58^m—17^h 35^m. (Lantern slide.)
(Plate 5.)

In this photograph, the tail of the comet is straight. It consists, at some distance from the head, essentially of two branches. The western branch is sinuous, as if matter were streaming irregularly back from the head, while the northern is very straight. At the end of the tail is a condensation which is nearly separated from the main tail.

A slender thread of light, beginning in the hinder part of the tail, stretches nearly to the end of the tail and forms the western border of the diffused western part of the tail. Near the head of the comet the tail is very slender and there are several small whisker tails from the rear of the head.

There is a small meteor trail crossing the south-western part of the plate parallel to the comet's tail.

1893 November $13^d\ 15^h\ 25^m$—$17^h\ 30^m$. (Lantern slide.)
R.A.S., No. 61.

This photograph perhaps properly belongs to the set of meteor pictures.

In the original negative the tail of the comet is shown in a straggling manner for some distance beyond the bright star (*α Can. Ven.*)

Perhaps the most singular thing about this picture is the fact that, though it was made on the morning of November 14, when there was a considerable number of bright Leonids, the great meteor shown on the plate was not a Leonid, for it was coming from the north, approximately towards the Leonid radiant. The meteor was seen with the eye as it shot across the sky and burst just off the region of the plate, but unfortunately the exact time was not recorded. It would not, however, be far from the middle time of the exposure. It was very brilliant—brighter than *Venus* at her greatest brilliancy.

Photographic Discovery of Comet V., 1892.

1892 October $12^d\ 6^h\ 40^m$—11^h. (Lantern slide, enlarged.)

$$\alpha = 19^h\ 32^m;\ \delta = +12°\ 50'.$$

This comet was the first one to be discovered by the photographic plate. A photograph north and west of *Altair* was made, in my regular work of photographing the Milky Way. When the plate was developed and examined, a short hazy trail was found on it in $\alpha = 19^h\ 32^m$, $\delta + 12°\ 50'$ (see *A.J.* 277). It was at once seen that the object was a stranger, as I was perfectly familiar with that part of the sky. It was too late to look it up that night with the telescope, but the next night it was sought for and found to be a very faint comet moving to the south-west. The discovery was telegraphically announced and the comet was generally observed. The orbit proved to be of short period—about $6\frac{1}{2}$ years.

Gale's Comet, 1894.

1894 May $5^d\ 8^h\ 45^m$—$11^h\ 15^m$. (Lantern slide.)

This is a characteristic photograph of the comet, which was mainly remarkable for the slenderness of its tail.

In this picture the tail is thread-like for some distance from the head. Further away it broadens out slightly, and separates into two or more parts. The northern edge of the tail appears to have a double curvature.

The phenomena presented by this comet were not very striking, though the changes in the tail were interesting. Only very slight traces of the tail could be seen with the telescope, and

these only quite close to the head, which was large and round, and did not seem to have anything to do with the formation of the tail, that is, there was no indication of the customary blending of the head into the tail.

Photographs of Meteors.

A nearly stationary meteor, 1894 August 9^d 14^h 17^m 4^s. (Lantern slide.)

This is the time of the meteor's appearance. It was nearly stationary, with a short path about 12′ long. The motion was from the north-east to the south-west. The original plate shows two other fainter meteors.

A number of other meteors were photographed at different times during my work at Mount Hamilton, but this stationary meteor and the one shown on the photograph of Brooks's Comet, 1893 November 13, are the most remarkable.

1897 August 10^d 15^h 19^m—15^h 49^m. (Lantern slide.)

This photograph was obtained with the Clark 3·4-inch doublet, which was kindly lent by the family of the late Alvan Clark, and which is a miniature of the Bruce 24-inch, and made from the same glass as that lens. The full flight of the meteor is shown on the plate. Before disappearing it burst, and beyond this point it left a faint trail as it died away. This gives the trail the appearance of a long shafted lance. Its path extends from $\alpha=2^h\ 59^m$, $\delta=+32°$ to $\alpha=2^h\ 59^m$, $\delta=+23°$.

1897 August 10^d 15^h 19^m—15^h 49^m. (Lantern slide.)

This is the same meteor. The picture was made with a small lantern lens 1·6 in diameter belonging to Professor Hale.

This photograph not only shows the meteor train, but it also shows the Pleiades near the lower east part of the plate. It is a very beautiful picture apart from its scientific value. These two photographs were made at the Yerkes Observatory.

These meteor photographs were reproduced and fully described in *Popular Astronomy*, No. 46.

Photographs of the Milky Way.

Star Cloud in Sagittarius.

1892 June 29^d 9^h 25^m—13^h 55^m. (Lantern slide.)

$\alpha=18^h\ 10^m\pm$; $\delta=-20°$.

This plate shows a large star cloud in Sagittarius, remarkable for the two black holes in it. Running southwards from the larger and more definite of these holes is a semi-vacant region, which

branches out into two more or less regular semi-vacant lanes, which run for nearly a degree and a half from the hole. At the junction of these lanes, about 50′ from the hole, is a remarkable thread-like stream of small bright stars which extends about 20′ east and west. Curving slightly at its east end this line of stars makes a V-shaped connection with two or three other bright stars. At the southerly ends of the dark lanes are two delicate, thread-like streams of stars; the southern one of these extends in a gentle curve for nearly 1½ degree. This is a very striking phenomenon. A similar stream runs eastwards from near the upper part of the black hole. Indeed, this is a remarkable region for star streams, many of which can be picked out on this plate. In the northern part of the slide is shown the celebrated Omega Nebula, which loses its characteristic appearance on account of the greater extent of nebulosity which the photograph shows compared with what the eye sees. The nebulosity extends in a very diffused, fan-shaped manner for over half a degree to the eastward from the brighter portion.

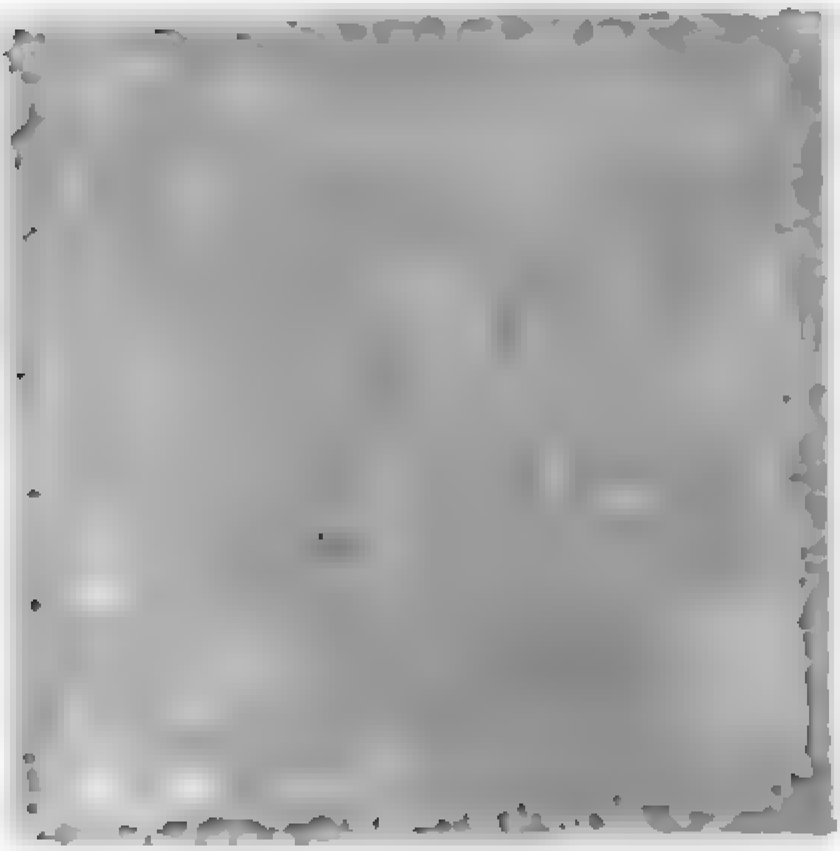
About 1½ degree south of the black hole is a group of nebulous stars. The largest star of this group is surrounded with a circular nebulosity some 20′ in diameter. Three degrees south of the hole is a bright star, with a partial ellipse of small stars extending south-eastwards from it. There are many other remarkable features about this plate, which will be at once apparent to the eye.

Near θ Ophiuchi.

1894 July 6^d 9^h 30^m—13^h 5^m. (Lantern slide.)

$\alpha = 17^h\ 15^m$; $\delta = -25°$. (Plate 6.)

This is certainly one of the most remarkable regions of the Milky Way. One would hesitate before coming to a conclusion as to what the ground work here is. Whether it is stars altogether, or some nebulosity, or something else, which is neither stars nor nebulosity (for it does not closely resemble either), it would be difficult to decide in one's mind. Besides the bed work of small stars, there seems to be possibly an infusion of nebulous matter over a large portion of the sky in this region. To the east and south of *θ Ophiuchi* is a vast chasm or rift in the sheetings of stars. This has a ragged but definite appearance on its western edge, but is more diffused to the east. To the west of the star θ will be seen an extended mass of diffused matter among the stars, which runs southward and partly bridges the western branch of the great rift. At the extreme western end of this rift—beyond the hazy diffusion—the vacancy has dark spots in it. Similar appearances occur at different points in this part of the sky. One can scarcely conceive a vacancy with holes in it, unless there is nebulous matter covering these apparently vacant places in which holes might occur. The appearance is somewhat like what



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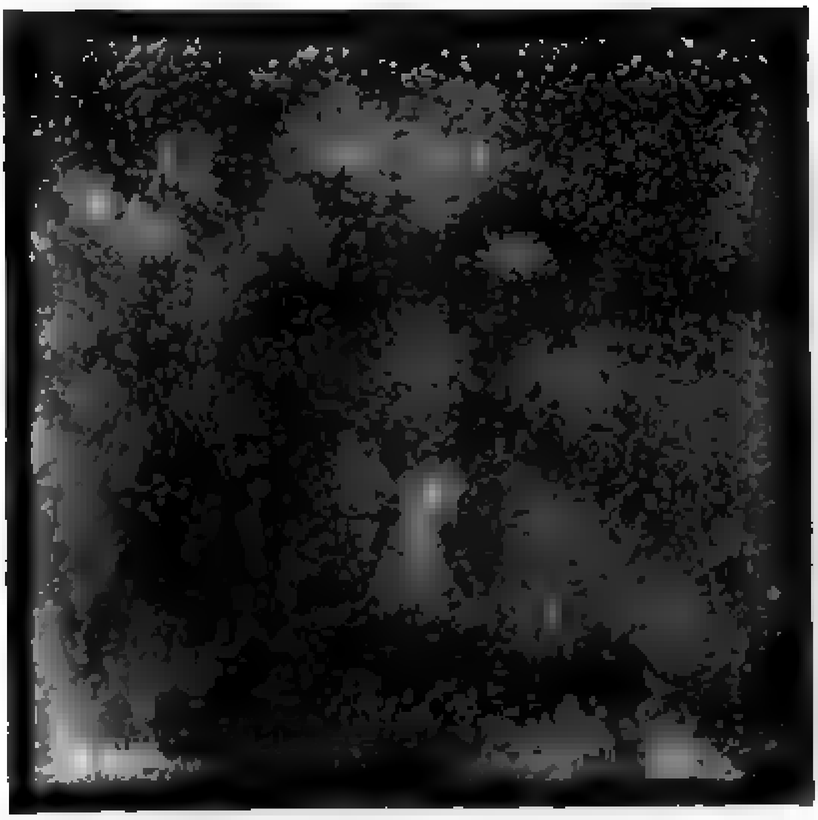
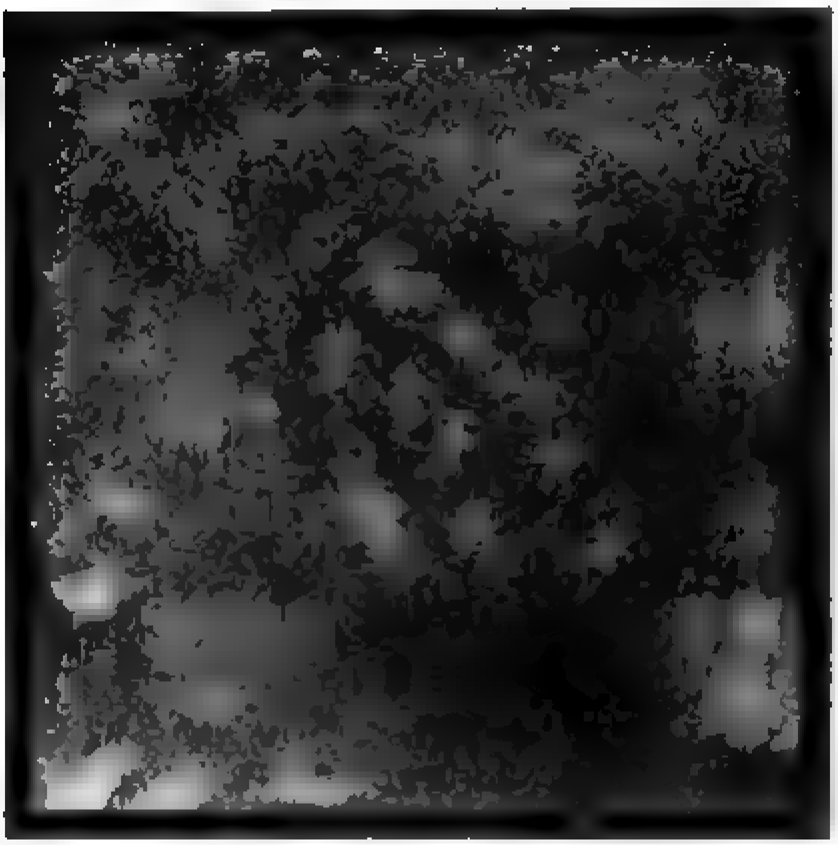


MILKY WAY NEAR θ OPHIUCHI, 1894 July 6^{d} 9^{h} 30^{m}—13^{h} 5^{m}.



THE REGION OF 58 OPHIUCHI, 1895 June 26^{d} 10^{h} 10^{m}—14^{h} 15^{m}.

is sometimes seen in the umbra of a sunspot, in which yet blacker holes appear. North of θ are several minute black markings, one of which very much resembles the letter S or the figure 5. Two almost parallel semi-vacant streaks, running north and south, will be seen on each side of θ. Still farther north of θ the Milky Way presents a broken appearance, with numerous holes and rifts. These all show the peculiarity of darker interiors. This is specially shown in another photograph I have made with that region central.

This picture is suggestive of a breaking up or segregation of the stratum of stars and nebulosity—I am not sure it is nebulosity—in this portion of the Milky Way.

North of θ Ophiuchi.

1895 June $25^d\ 9^h\ 55^m$—$13^h\ 55^m$. (Lantern slide.)

$\alpha = 17^h\ 15^m$; $\delta = -22°$.

This photograph shows still better some of the phenomena of the preceding picture. It brings out yet more remarkably the extraordinary nature of the holes and rifts in this part of the Milky Way. The phenomenon of darker holes in the vacancies is strikingly shown, and looking at the picture one cannot repress the thought that all this region of the Milky Way must have a substratum of nebulous matter mixed in freely with the ground work of stars.

The Region of 58 *Ophiuchi.*

1895 June $26^d\ 10^h\ 10^m$—$14^h\ 15^m$. (Lantern slide.)

$\alpha = 17^h\ 35^m$; $\delta = -22°$. (Plate 6.)

This region joins on to the preceding one. It is quite unique, however, and the peculiar appearances shown on this plate are not repeated in any other part of the Milky Way.

The bright star in the middle of the slide is 58 *Ophiuchi.* This star occupies the centre of a most remarkable region of small, cloudlike masses, which in arrangement seem to have a slight spiral tendency. This region, like that of θ *Ophiuchi*, is one where some doubt as to the existence of slight nebulosity might arise. I do not feel certain, however, that these clouds are nebulous, for there is lacking that peculiar soft appearance always characteristic of the true nebulosities of the sky.

The Trifid Nebula and M. 8 are shown at the east edge of the plate. The cluster in the north-east quarter is M. 23.

This plate also shows the trail of an asteroid, which Dr. Berberich kindly identified as belonging to *Euterpe* (27), which was discovered in 1853 by Hind. To those interested in this planet the trail will be found $1\frac{1}{2}$ degree south of 58 *Ophiuchi.*

It will be easily found on the large 10 × 8 glass positive in the possession of the Royal Astronomical Society, which is from the same negative as the present lantern slide. Indeed, it can be picked out on the slide with a magnifier, 0·32 inch almost due south of 58 *Ophiuchi*, in a semi-vacant region, between two of the clouds.

The Nebulous Region of 15 Monocerotis.

1894 February 1^d 7^h 0^m—9^h 25^m, clouds then 9^h 50^m—10^h 25^m. (Lantern slide.)

$\alpha = 6^h\ 35^m$; $\delta = +10°$.

This plate shows well the large diffused nebulosity that extends some 3 degrees northwards from the condensed region about 15 *Monocerotis*. The nebulosity spreads over and partly veils a portion of the great vacancy which lies north and west of 15 *Monocerotis*. To the west of 15 *Monocerotis* is a curious nebula involving several considerable stars. In the upper part of this nebula are one or two remarkably small black holes. This object, which is extremely faint and diffused visually, was discovered with the 12-inch in 1888. The position of this nebula is 1860·0 6^h 23^m $27^s + 10°$ $7'$. It involves the two D.M. stars $+10°·1159$ and $+10°·1160$. Close north of this nebula is a small nebulous star which was also discovered with the 12-inch in 1888. Its position is 1860·0 6^h 23^m $14^s \pm$, $+10°$ $32'·6 \pm$. There is also a small vacancy in the nebulosity about this star, close south of the star.

At the south edge of the plate is shown a portion of Swift's nebula N.G.C. 2237.

If the plate is carefully examined, many curious lines of stars, vacant lanes, &c., will be seen. About 2 degrees south of 15 *Monocerotis* is one of these thin lanes or dark lines among the stars which, though extremely narrow, runs eastward for about 2 degrees.

Region of M. 11.

1895 August 16^d 8^h 25^m—13^h 35^m. (Lantern slide.)

$\alpha = 18^h\ 45^m$; $\delta = -6°$.

This magnificent star cloud is beautifully shown on this plate It was one of the first of the Milky Way clouds photographed in 1889.

The small cluster M. 11 lies on the upper or north edge of the neck of the large cloud, and looks like a nucleus. The western side of the great cloud has several rather sharply marked indentations and several detached masses of stars.

The star 6 *Aquilæ*, on the upper north edge of the great head, has two curious sprays of stars extending from it, giving the

appearance of a ram's horns. The great star cloud seems to be made up of very small stars, apparently very uniform in size. Near the left-hand corner of the plate is shown a beautiful bright nebulous star. This is S.D.M. 10°·4713 of the 5·5 magnitude. The position for 1855·0 is $18^h\ 23^m\ 23{\cdot}9^s$, S. 10° 53·4′. The nebulosity about this star is somewhat elliptical. It was discovered on the plates of 1889, and is quite noticeable visually (See *Ast. Nach.* 3111, Bd. 130.) The bright star near the N.E. edge of the plate is λ *Aquilæ*. The great star cloud seems to stretch out to and surround this star.

Region of M. 8 and the Trifid Nebula.

1895 June $27^d\ 10^h\ 55^m$—$14^h\ 25^m$. (Lantern slide.)

$\alpha = 18^h\ 0^m$; $\delta = -24°$.

This slide is intended to show the appearance of the Milky Way in the immediate neighbourhood of these two nebulæ. It gives an excellent idea of the apparent relation they bear to the rest of the Milky Way. They appear to lie just free of the western border of a very brilliant portion of the Milky Way, in a partially vacant region, between the bright clouds and the region of 58 *Ophiuchi*. South of these objects is one of the most beautiful of all the regions of the Milky Way.

M. 8 and the Trifid Nebula.

The same as the preceding, on a larger scale.
(Lantern slide.)

This is intended to give a closer view of these objects, and to show their relation to each other and to a group of nebulous stars which lies about 1° east of M. 8. The latter is a very remarkable group. The stars are not simply involved in nebulosity, but each one is a distinct nebulous star. They are connected on the photographs by a delicate nebulous strip with M. 8. Several of these were originally discovered visually with the 12-inch.

In reference to this picture it is well to note one thing which might be misleading when compared with photographs of these objects with larger instruments, where the scale is greater. In dealing with the fainter and outlying portions of M. 8 the portrait lens is eminently suited, but for the details of the brighter parts a larger scale becomes necessary. These details are too crowded with the small scale, and the light action is so great that what are apparently vacant lanes and regions with a larger instrument are filled up and obliterated with the long exposure, thus producing an apparent difference in the appearance of the nebula with the portrait lens and with a greater telescope. For the details the difference is in favour of the larger telescope for a truthful representation of the nebula; or,

in other words, the small bright details of this nebula are not suitable subjects for a short-focus portrait lens, especially when using such long exposures as are required to bring out the fainter portions of the Milky Way. A comparatively short exposure would show these details more faithfully.

Great Star Cloud in Sagittarius.

1895 August 13^d 8^h 0^m—11^h 8^m. (Lantern slide.)

$\alpha = 17^h$ 56^m ; $\delta = -28°$. (Plate 7.)

This is a superb picture of the Milky Way. It most emphatically shows the great value of the portrait lens for work of this kind, where large details, covering a great region, are to be dealt with.

This beautiful region has always had a special charm for me, and I have secured a great many photographs of it. It was the first region to be photographed in 1889.

I can hardly believe that any one familiar with the sky can look on this picture without admiring the beauty of structure and detail shown on it. Outside of its scientific value, it is a picture in itself.

To the west of the centre is a great plume-like spray of stars that apparently is connected with a long rope-like nebula and streak of stars running nearly north and south for nearly 2 degrees. This nebulous rope of stars is a very singular feature. In some photographs of the region which I made with the small lantern lens it seems to stand out from the other details near it as if it were considerably nearer to us and not connected with the star plume, as it appears to be in this photograph.

In the bright region near the centre of the plate is a tiny black hole about 2′ or 3′ in diameter, well defined, and close preceding a small bright group of stars. It is so small and well defined on the plate as to look like a defect. The position of this object is 17^h 56^m—$27°$ $51'$ (see *A.N.* 2588). It is a most remarkable object, with a low power on a 5 or 6-inch telescope. In examining this hole with the 36-inch, I found that its southern edge was made up of a dense mixture of milky nebulosity and small stars.

In the north part of the plate is shown M. 8 and the Trifid Nebula.

The Great Nebula of ρ Ophiuchi and the Vacant Regions near Antares.

1895 June 21^d 9^h 12^m—13^h 12^m ; June 22^d 9^h 5^m—13^h 35^m. (Lantern slide.)

$\alpha = 16^h$ 20^m ; $\delta = -23°$.

It is very difficult to attempt a description of this picture. In the centre of the plate is the great nebula, in the centre of which *ρ Ophiuchi* is apparently placed. But this is only the

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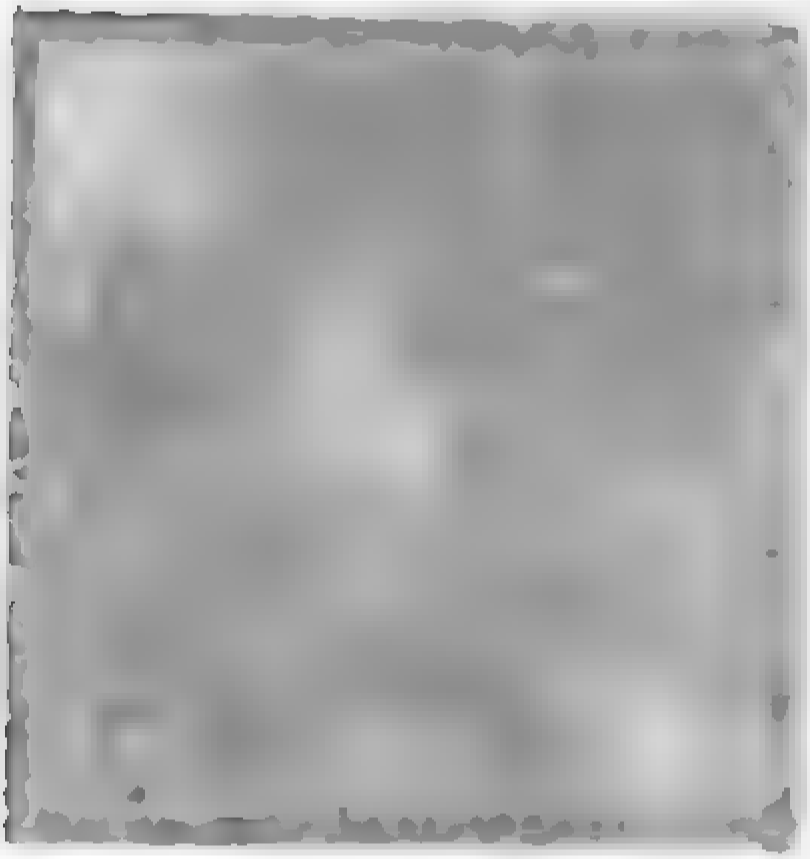

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Great Star Cloud in Sagittarius 1898 August 12^d 9^h 0^m—11^h 8^m.

Region near the Omega Nebula (M. 17), 1898 July 25^d 9^h 25^m—14^h 0^m.

[redacted]

main condensation of this remarkable nebula. Its influence seems to be very far-reaching, as it has secondary condensations about at least two other stars, viz. Cordoba D.M. $24^{\circ}\cdot12683$ and $24^{\circ}\cdot12684$ and 22 *Scorpii*. The one about the Cordoba stars is the most striking, and seems to be made up of four curved streams, like the whirls of a great spiral. The great condensation about ρ *Ophiuchi* is most highly suggestive, and with a larger telescope would, no doubt, prove to be a most extraordinary object, as there are a great many remarkable details shown even on this small scale.

The great nebula occupies a vacant region from which vacant lanes stretch irregularly for great distances to the east. One remarkable feature about these dark lanes is the peculiarity before mentioned, of darker places in the vacant regions; this is strikingly shown in the present photograph. A nebulous prong is seen extending northwards for a short distance from the bright star, σ *Scorpii*, which is evidently connected with the great nebula. A large portion of the sky here seems to be covered with diffuse nebulosity, to which belongs the condensation about ρ *Ophiuchi* and the other stars. The peculiarity of this region has suggested to me the idea that the apparently small stars forming the ground work of the Milky Way here, are really very small bodies compared with our own Sun. (See *Popular Astronomy*, No. 45, where the subject is discussed in detail.)

In the upper north-west corner of the picture is the star ν *Scorpii*, which is seen to be involved in a singular wing-like nebula. East and south of ν are the two stars S.D.M. $19^{\circ}\cdot4358$–9 and 4361, which are involved in dense nebulosity. The star 4361 is in the position $1855\cdot0$ $\alpha = 16^{h}\ 12^{m}\ 1^{s}$; $\delta = -19^{\circ}46'$.

These objects were none of them known previous to the first photographs I secured of this region in 1895 March, with the exception that I had known of nebulosity in this region for many years through my comet sweeping.

I am glad to hear that Professor S. I. Bailey expects to take this great nebula up with the Bruce 24-inch at Arequipa, at its next apparition, as well as several other objects of this kind. The results will be exceedingly interesting.

The Nebula about ν Scorpii.

1895 May $23^{d}\ 9^{h}\ 0^{m}$—$12^{h}\ 20^{m}$. (Lantern slide.)

$\alpha = 16^{h}\ 5^{m}$; $\delta = -19^{\circ}$.

ν *Scorpii* is one of Mr. Burnham's double stars. In photographing the region of the great nebula of ρ *Ophiuchi* in 1895 March, I made exposures at the same time with the $1\frac{1}{2}$-inch lantern lens. On the photographs, with this small lens, the star ν *Scorpii* was seen to be involved in dense nebulosity. This star fell at the edge of the Willard lens plate, but upon examination it was seen

that the larger lens had also shown the nebulosity, and this was repeated in subsequent pictures. The present plate is from a negative made with the Willard lens specially to show the nebula. It is seen to be a wing-like nebulosity, extending north, west, and south-east, with the bright star occupying, apparently, the centre of brightness. The nebula extends eastwards for some distance, where it seems to dull the sky, or where there are very few stars. It is well defined and brightest at its western edge. The photographs indicate that this nebula is probably connected with the great nebula of *ρ Ophiuchi*.

Region of β Cygni.

1893 October $12^d\ 6^h\ 52^m$—$11^h\ 35^m$. (Lantern slide.)

$\alpha = 19^h\ 25^m$; $\delta = +26°$.

This picture shows the cloud forms in the Milky Way, south and east of *β Cygni*.

Some 5° east of *β* the dense clustering of small stars rather abruptly terminates in great cloud masses. Beyond this the Milky Way is very thin, and permits the darkness of space to be seen between the stars. One is specially struck with the apparent extreme smallness of the general mass of stars in this region.

Region near χ Cygni.

1892 October $20^d\ 6^h\ 47^m$—$11^h\ 47^m$. (Lantern slide.)

$\alpha = 19^h\ 40^m$; $\delta = +33°$.

This region lies south of *γ Cygni*, which is seen in the north-east half of the photograph.

The north-west part of the plate is covered with a more or less uniform sheet of small stars, so densely crowded as to intercept the view of space beyond, while the south-east portion is overspread with a very thin sheeting of stars projected against the blackness of space. The contrast between the two conditions is very beautiful and striking. The stars here are also remarkably uniform in size.

The original negative shows a great deal of nebulosity about *γ Cygni* in the form of brightish strips and patches, which slightly give the impression of a spiral arrangement to the nebulosity; these have been sacrificed, however, in the slide to show the structure of the Milky Way to the best advantage.

Nebulous Region near α Cygni.

1893 October $5^d\ 8^h\ 0^m$—$14^h\ 5^m$. (Lantern slide.)

$\alpha = 21^h\ 0^m \pm$; $\delta = +42° \pm$.

The plate shows the singular structure of the Milky Way at this point, and the great nebulosities that affect the sky in this

region. It will be seen that the greatest mass of nebulosity seems certainly to be mixed up with the stars, and conforms with the outline of the star masses at the edge of the greatest semi-vacancy. This region was first photographed by Dr. Max Wolf. The nebulosities are easily seen with almost any sized visual telescope when a low power is employed. I was for many years familiar with the nebulosity when seeking for comets, though I did not take it for real nebulosity. Indeed, this very nebulosity was discovered by William Herschel. In a list of great masses of diffused nebulous matter, in *Phil. Trans.* for 1811, pp. 273–278, he gives for number 44 of his list (1800·0 $\alpha = 20^h\ 51^m\ 4^s$ P.D. $46°\ 51'$), with the note : "Faint Milky Nebulosity scattered over this space ; in some places pretty bright." He gives the size in declination as $0°\ 59'$, and in right ascension $2°\ 53'$, or 2·8 square degrees in area. This is undoubtedly the object shown on the photographs.

Region of N.G.C. 6475.

1894 June $26^d\ 9^h\ 5^m$—$12^h\ 10^m$. (Lantern slide.)

$\alpha = 17^h\ 45^m$; $\delta = -35°\ 0'$.

This beautiful cluster is partly in a brilliant knot or condensation of the Milky Way.

About 3° north-east of the cluster is a small semi-vacant comma-shaped hole with a considerable star in its centre. This hole is about 12′ in diameter.

The Milky Way in Cepheus.

1893 October $13^d\ 8^h\ 20^m$—$15^h\ 20^m$. (Lantern slide.)

$\alpha = 21^h\ 35^m$; $\delta = +57°$.

Near the centre of this plate is a large and singular nebulosity, remarkable for the irregular dark lanes that run into and through it. My first knowledge of this nebula was its presence near the edge of another plate. The present picture was made specially to see what the object was. It was found, as shown, to be a fine but very singular-looking nebula.

To the extreme west of the plate, and north of the centre, are two small stars near each other. One of these is strongly nebulous. It is one of Mr. Burnham's double stars (β 1140), while the other star close following it is Σ 2790. The larger star south of the centre of the plate is μ *Cephei*, while the one at the north edge is ν *Cephei*.

Region near the Omega Nebula (M. 17).

1895 July $25^d\ 9^h\ 35^m$—$14^h\ 0^m$. (Lantern slide.)

$\alpha = 18^h\ 30^m$; $\delta = -15°$. (Plate 7.)

This is a very interesting region. The centre of the plate is covered by a large mass of stars which converges to a point at a vacant region in the north part of the plate. Indeed, nearly all the masses of stars in this region seem to tend towards this great vacancy, as if its formation had something to do with their general arrangement. In this hole shines the beautiful nebulous star previously mentioned (S.D.M. 10°·4713), which is perhaps better shown on this plate than on the others. To the south-west of the centre of the plate is the celebrated Omega or Swan Nebula (M. 17), and at the lower south-west corner is the fine star cloud, with the dark holes previously mentioned.

All the times given in these descriptions are eight hours slow of Greenwich, except the two plates made at the Yerkes Observatory, which are six hours slow of Greenwich. The positions given for all the pictures are only very roughly approximate.

It is perhaps well to state that in none of my work has any retouching been resorted to. Every photograph is free from any blemish of that kind, which, however it may be tolerated in a portrait of the human face (and it is destructive enough of truth there), should never be permitted to vitiate the value of an astronomical photograph. A defacing scratch, or a misleading defect, should be removed, but on no account should results be sought for that cannot be got by a skilful and straight development.

In conclusion, I wish to express my sincere obligations to Mr. G. W. Ritchey, of this Observatory, who has kindly and skilfully made for me nearly all of the lantern slides here presented.

Yerkes Observatory, Williams Bay, Wisconsin:
1898 November.

Errata in Professor Herschel's paper, vol. lix.

Page 184, line 2 from bottom, *for* Dr. Downing *read* Mr. Denning.
,, 186, first column of the table, *for* ☄ 1680 ☌ *read* ☄ 1680 ☋.
,, ,, heading of the second and third columns of the table, *for* Cometary "Appulse" (☌) *read* Comets' Node and Appulse.
,, 189, line 15, *for* 21 *read* 27.
,, 190, line 2 from bottom, *for* 117 *read* 177.

// MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIX. APRIL 14, 1899. No. 7

Professor G. H. DARWIN, M.A., LL.D., F.R.S., President, in the Chair.

Ernest William Barnes, B.A., Trinity College, Cambridge;
Samuel Chatwood, F.R.G.S., Broad Oak Park, Worsley, near Manchester;
Rev. W. B. K. Francis, H.M.S. *Boscawen*, Portland; and
Capt. Windeyer George Lingham, 1 Caldervale Road, Clapham, S.W.,

were balloted for and duly elected Fellows of the Society.

The following Candidate was proposed for election as a Fellow of the Society, the name of the proposer from personal knowledge being appended:—

Frederick Evan Peach, Schoolmaster, 161 Stanstead Road, Forest Hill, S.E. (proposed by J. E. Evans).

Eighty presents were announced as having been received since the last meeting, including, amongst others:—

Astronomici Veteres, Venetiis (Aldus), 1499, presented by W. Arthur Smith; Dunsink Observations, Part VIII., presented by the Observatory; Greenwich Observations, 1896, presented by the Observatory; Moore's Almanac, 1865–94, presented by Rev. S. J. Johnson; Palisa und Bidschof, Katalog von 1238 Sternen,

auf Grund der Meridiankreisbeobachtungen der von Kuffner'schen Sternwarte, presented by the authors; Pulkowa Observatory, Ascensions droites moyennes des étoiles principales, par A. Sokolov, presented by the Observatory; H. Struve, Beobachtungen der Saturnstrabanten, presented by the Pulkowa Observatory; Venus Durchgänge, 1874, 1882, Bericht uber die deutschen Beobachtungen, Band I., herausg. von A. Auwers, presented by the German Transit of Venus Commission; L. Weinek, Photographischer Mond-Atlas, Heft 4, presented by Professor Weinek.

Observations of Hind's Variable Nebula in Taurus (N.G.C. 1555), made with the 40 inch Refractor of the Yerkes Observatory. By E. E. Barnard.

In *Monthly Notices, R.A.S.* for 1895 June, I have given a historical account of the celebrated variable nebula of Hind (N.G.C. 1555).

This object was discovered by Mr. J. R. Hind 1852 October 11, at Mr. Bishop's Observatory, London, and his original account of the discovery will be found in *A.N.*, No. 839.

When discovered by Hind, and for some years subsequently, this nebula was a conspicuous object in an ordinary telescope. It was seen and measured by D'Arrest, Struve, and Lassell, and was close south, preceding a small star since known as the variable *T Tauri*.

About 1860 the nebula had disappeared in ordinary telescopes, and by 1868 it seems essentially to have also vanished from the largest instruments.

In 1868 Struve found another small nebula 4′ preceding the place of Hind's. This object was afterwards observed by D'Arrest and Tempel. The latter saw this nebula 1877 November 8. It was $1\frac{1}{2}'$ in diameter, with a small star in the northern portion of it. On December 12 of the same year it had disappeared from Tempel's telescope, but two small stars were visible at its place, the northern of which was the one seen on November 8 in the nebula 40″ south, following the centre.

These objects seem to have been neglected after this until the fall of 1890, when Mr. Burnham took up the subject with the 36-inch (*Monthly Notices*, 1890 December, also *Pub. L.O.*, vol. ii., p. 175). I was kindly invited by him to share in the observations.

From the fact that he found *T Tauri* to be the nucleus of a small extended nebula, and that, by a singular coincidence, that star's position in the D.M. was erroneous by a quantity that made it exactly coincide with the position of Hind's nebula, Mr. Burnham concluded the star with its nebulosity was the variable nebula

itself. While observing with him, I detected a very faint round nebula, close south preceding the star, and entirely disconnected from it. This nebula was supposed by us to be new and unknown, as it was unlikely that any other telescope could have shown it.

Remembering this nebula a few years later, it occurred to me to look it up and determine its position. It was therefore sought for on 1895 February 25, and was easily found. It appeared somewhat brighter than in 1890, and was an easy object. (It was actually seen on February 26 with the 12-inch.) I measured its position with reference to *T Tauri* and, upon looking up the place of that star, found to my surprise that the position in the *D.M.* was in error. With the true place of *T Tauri* my nebula came out identical in position with Hind's variable nebula of 1852! To my further surprise I found that the very definite and brightish nebula, which Mr. Burnham had found *T Tauri* the nucleus of, and which I had seen with him, had entirely disappeared! There seemed to be, however, some feeble traces of nebulosity surrounding the star, but the distinct nebula of 1890 was gone.

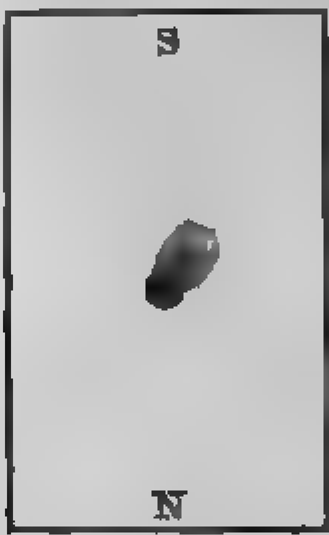
At no time could either Mr. Burnham or I see any traces of Struve's nebula, 4′ preceding these objects, though we looked carefully for it. In my observations of 1895, however, I measured a small star that essentially occupied the place of Struve's nebula, and which was undoubtedly the brighter of the two mentioned by Tempel in 1877, and which D'Arrest had spoken of previously as being the eccentric 14-mag. nucleus of Struve's nebula; but I did not see any second star.

This region was again examined with the 36-inch in the following September, on the 15th, 22nd, and 23rd, under the very finest conditions. No trace of Hind's nebula could be seen. It had absolutely disappeared in the great telescope. Every effort was made to see it, by occulting *T Tauri*, by the use of different magnifying powers, &c. (*Monthly Notices* for 1895 December). *T Tauri* itself seemed unchanged from its appearance in the previous February and March. Nothing was visible of Struve's nebula. A second and much fainter star, however, was seen south of the small one previously measured at this point, and this must have been the second of Tempel's stars. It was at the limit of the 36-inch under the finest conditions, and was estimated at 17th magnitude. This small star must therefore have faded greatly since Tempel's observations of 1877, for it would have been impossible for him to see it with 11 inches aperture.

I have thus briefly sketched the history of this singular region as a prelude to my observations of it here with the 40-inch. I would, however, refer those interested in the matter to the more detailed papers in *Monthly Notices* for 1895 June and December.

One of the first things examined here with the 40-inch was *T Tauri* and the region of Hind's and Struve's nebulæ. These observations were begun 1897 September 20. The seeing on

this date was fair, but there was no trace of either of these nebulæ, and *T Tauri* appeared unchanged. The brighter of the two small stars was seen at the place of Struve's nebula.



T Tauri, 1897 September 22, &c.

On September 22 no trace of either nebula was seen, though the conditions were fair. But, upon close examination, *T Tauri* was seen to have a very small and very close nebulous patch attached to it on the following side. This was seen with various magnifying powers. At first the star appeared to be double, but the higher powers showed the appearance to be due to a very small nebula or nebulous patch very close south following the star, perhaps from 1″ to 2″ distant.

September 26, Mr. Burnham and I examined *T Tauri* and the region of Hind's and Struve's nebulæ. No trace of these objects was seen. *T Tauri* appeared as in the observations of 1895. Nothing whatever was seen of the small brightish nebula in which it shone in 1890. The seeing was not quite good enough to see the small nebulous patch of September 22.

September 28, with good seeing, Hind's nebula could be very faintly seen, but with the utmost difficulty, occupying the position of 1890 and 1895. It was excessively faint and difficult, but seen with certainty; it was at the limit of vision, and could not have been brighter than the 17 magnitude. The small nebulous patch close s.f. *T Tauri* was seen. No trace of any nebulosity existed at the place of Struve's nebula. The small star at that point seemed considerably brighter than formerly. The small star south of this was visible, but it was excessively faint and at the limit of vision. Its position was measured with reference to the brighter of the two.

Position angle, 193°·2 (3); distance, 18″·25 (3). The measures were made with the utmost difficulty.

October 26. Sky too thick, but the brighter of the two small stars was visible.

November 2. Sky white from moonlight. Could see the fainter of the two small stars (as also the brighter one), but with the utmost difficulty. Sometimes this very faint star appeared like a very faint, very small nebula 1″ or 2″ in diameter. This, however, was uncertain. It also appeared nebulous to me with the 36-inch in September 1895. But an observation of this kind, at the limit of vision, cannot be depended on.

November 23. Sky thick, and the seeing too bad to make out anything.

1897 December 25. Examined very carefully; nothing seen of the Hind or Struve nebula. The two small stars were visible however—the faint one for only a moment.

1898 September 26. Perhaps faint traces of Hind's nebula could be made out, but not with any certainty. The two small stars at the place of Struve's nebula were visible—the northern one quite bright, the other excessively faint.

October 10. No trace of Hind's nebula with any certainty. The northern of the two small stars pretty bright—11^{m} or $11\frac{1}{2}^{m}$. Seeing fearfully bad; the stars boiling.

December 10, $7^{h}\ 40^{m}$. Only the vaguest glimpses of Hind's nebula made out, but it was certainly seen by hiding *T Tauri*. Conditions were fairly favourable. The two small stars were visible, but nothing of Struve's nebula. The south star was excessively faint, but was fairly well seen. Observed again at $11^{h}\ 30^{m}$, but seeing too poor to do anything.

I have never seen anything of the two small stars shown in Tempel's sketch in *Ast. Nach.* 2212 close north preceding *T Tauri*.

In conclusion, we have evidence that Hind's nebula still exists, but in a most excessively faint condition in the most powerful telescope under the very best conditions.

It is possible that these glimpses of the nebula seen here are due to slight fluctuations in its light. The observations of 1895 show that from an easily visible object in February and March of that year it had utterly disappeared in the same telescope (36-inch) six or seven months later. It was brighter in 1895 than in 1890.

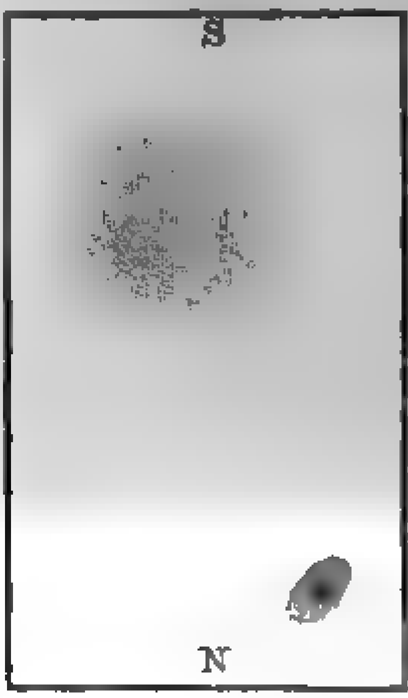
Whether its visibility in 1890 was due to an increase of its light after it was lost sight of many years before, or was simply due to the more powerful telescope, we have no means of telling. But it had certainly brightened up in the spring of 1895, and as certainly faded very greatly soon after that.

Whether the light of this nebula is approaching absolute extinction, or is simply subject to great fluctuations, will be an interesting question for the future to decide.

From the early accounts of the nebula, one is impressed with the idea that it had not long been of its brightness when Hind found it in 1852. If so, we should probably again see it with small telescopes. It is, therefore, worthy of a close watch. At present this must be done with powerful telescopes, for it is of that class of nebulæ which are best seen in a large telescope.

From the glimpses I have had of it lately, its faintness does not seem to be due to diffusion of its light over a larger area; it seems to be of the same size as formerly, and to have simply diminished in visibility through an actual loss of light.

I have lately found a note and sketch concerning the appearance of *T Tauri* and Hind's nebula at the observations of 1890 which should have been incorporated in my paper in the June 1895 *Monthly Notices.* As a matter of record it is well to introduce these in the present paper.



Sketch of *T Tauri* and Hind's Nebula 1890 Oct. 15.

"1890 October 15 at $13\frac{1}{2}^h$. Mr. Burnham and I looked at the place of Hind's variable nebula in *Taurus* with the 36-inch. There is an elongated pretty bright stellar nebula, very small, which Mr. Burnham saw the other night and measured [this was *T Tauri*]. I saw an extremely faint round diffused nebula $\frac{3}{4}'$ diameter almost due south of it [*T Tauri*], estimated position angle 185°, distance $\frac{3}{4}'$. It was feebly brighter in the middle. We saw nothing at the place of Struve's object 4′ preceding what we have assumed to be Hind's nebula [*T Tauri*]."

Yerkes Observatory, Williams' Bay, Wisconsin:
1899 *January* 27.

Periodic Variation in the Colours of the two Equatorial Belts of Jupiter. By A. Stanley Williams.

The very beautiful and often very pronounced colours of the belts of *Jupiter* have long attracted the attention of observers. When observing the planet in the year 1879 with a $2\frac{3}{4}$-inch refractor I was much struck by the colours of the two equatorial

belts. The north equatorial belt was then intensely red, whilst the south equatorial belt was not only devoid of all red colour, but was actually bluish. Two or three years later both belts were reddish coloured; whilst in 1884 the tints of 1879 were reversed, the south equatorial belt being now intensely red and the north equatorial belt bluish. These changes seemed so curious that I have since kept a nearly complete record of the colours of these two belts extending up to the present time. Subsequent to 1892 a definite scale has been used to express the degree of redness of the belts, ranging from 1 (the feeblest possible tinge of red) up to 10 (the reddest markings observed on the planet *). Previous to that year there are only verbal descriptions of the colours. These observations have all been recently reduced, in as uniform a manner as possible, by converting these verbal descriptions into terms of the numerical scale. The observations, when thus reduced, showed marked maxima and minima of redness, separated by intervals of about twelve years, and so arranged that the maxima of the south equatorial belt synchronised with the minima of the north equatorial belt, and *vice versa*.

These results were so decided and seemed so remarkable that I have treated all the accessible contemporaneous records in the same manner, namely, by converting the verbal descriptions of the colours into terms of my numerical scale. Every effort was made to make this part of the work as independent and free from bias as possible, and with this view care was taken not to make any comparison with my observations until those of other observers had been first reduced. The labour involved in this reduction has been considerable, there being an enormous mass of published and unpublished material, which all had to be carefully gone through.

When the results subsequent to 1878 had all been reduced in this manner, the earlier observations were treated in the same way. This part of the work, however, is not so complete as the later portion, as I have only been able to make a superficial search through the records of this period, and the observations available are not very numerous. Nevertheless, there is a continuous, and more or less perfect, record of the colours of the two belts down to the year 1867. Previous to this year there are, however, only a few isolated results until we come to a very remarkable series of observations by Gruithuisen. This observer has published a continuous record of the colours of the belts, extending from 1836 to 1846, illustrated by coloured drawings.

The results of these researches are embodied in the following table, in which the first column gives the date, and the second the mean degree of redness of the north equatorial belt. The third and fourth columns give the corresponding data for the south equatorial belt, whilst the last column contains references

* Namely, the red spot when at its reddest, and the short intensely red streak which was visible on the south temperate belt in 1891.

to the authorities on whose observations the results depend. Two figures joined by a hyphen in columns two and four indicate that the mean redness falls nearly midway between the two.

Mean Redness of the Equatorial Belts.

N. Equat. Belt.		S. Equat. Belt.		
Date.	Redness.	Date.	Redness.	Observers.
1786·74	3†	1786·74	3†	S.
1792·26	3	1792·26	3	S.
—	—	1835·91	4	Sc.
1836·36	0	1836·36	5	G.
1837·05	2	1837·05	4	G.
1838·04	3–4	1838·04	3–4	G.
1839·33	3	1839·33	3	G.
1840·25	3	1840·25	3	G.
1841·60	3	1841·60	3	G.
1842·25	4	1842·25	0–1	G.
1843·50	5	1843·50	0	G.
1844·44	3–4	1844·44	2	G.
1845·52	4	1845·52	2	G.
1846·56	2–3	1846·56	2–3	G.
1860·05	3†	1860·05	3†	Hl.
1862·31	3	1862·31	3	We.
1867·70	5*	1867·70	0	Gr.
1868·60	4†	1868·60	1†	Bu.
1869·64	3	1869·64	3–4	Bu., Bg., By., Gr., Ma., Sa.
1870·95	3†	1870·95	3†	Bg., Bi.
1872·03	2	1871·98	3	Bg., Bi., L., La.
1873·16	1	1873·25	5	Co., Gr., Kn., L.
1874·23	2†	1874·25	3†	Br., Gro., Kn., L.
1875·33	2–3†	1875·33	2–3†	Br., L.
1876·53	3	1876·52	3–4	Br., L., Hi., Td., Rd., Rl.
1877·50	4	1877·52	3	Br., D., Hi.

* The only observation is one by Mr. N. E. Green, who states that "the northern belt was very dark and brownish in colour; while the southern, though broader, was faint and grey." As Mr. Green usually describes the red colours less pronounced than do other observers, and, indeed, shows perhaps a partiality for bluish tints, I have entered the redness of the N. Equat. belt as 5 on the scale, though there is necessarily considerable uncertainty as to the exact figure.

† Results marked thus are only approximate, the observations available being insufficient to allow of a satisfactory estimate of the degree of redness to be made

N. Equat. Belt.		S. Equat. Belt.		
Date.	Redness.	Date.	Redness.	Observers.
1878·58	4	1878·62	0	C., D., L., N.
1879·72	5	1879·71	0	Bar., Br., Bt., D., Kt., L., N., T., W.
1880·70	5	1880·73	1	Bar., Ca., D., Fe., L., N., Rl., W.
1881·87	3	1881·87	1	B., Ba., C., E., Gt., Gy., N., T., W.
1882·93	0–1	1882·94	4–5	B., Be., Gr., Gt., T., W.
1884·05	0	1884·01	5	B., E., Fr., Ge., Go., Mg., O., Ri., T., W.
1885·24	[illegible]	1885·22	4	B., Ge., Le., Mi., Pe., Pr., Sm., T., W.
1886·20	3	1886·18	3	B., T., W.
1887·36	3	1887·36	3	T., W.
1888·30	3–4	1888·40	5*	W.
1889·45	3	1889·45	3	Ho., K., W.
1890·65	4–5	1890·67	1	Da., K., Me., Ry., Sm., T., W.
1891·72	6	1891·72	0	J., K., T., W.
1892·75	5	1892·78	2–3	A., Cr., Kl., M., W., Wa., Wh.
1893·85	4	1893·79	3	He., Me., W.
1894·83	[illegible]	1894·83	3–4	Bar., Bn., Da., W.
1895·85	3	1895·85	3	A., Cs., Ni.
1896·18	2	1896·15	4	Bn., F., Fo., Gf., Gl., M., My., P., R., W.
1897·29	0–1	1897·20	5	An., Cr., Da., Es., F., Fo., Gl., Gf., H., Ke., Ki., Q., R., Sh., Sm., To., W., Wa.
1898·29	4	1898·29	4	Ch., Cs., D., Gn., H., Hs., W.
1899·09	3	1899·09	3	P.W.

Abbreviations.

A.	=	E. M. Antoniadi.	Ca.	=	R. Capron.
An.	=	W. Anderson.	Ch.	=	H. Y. Childs.
B.	=	Otto Bœddicker.	Co.	=	R. Copeland.
Ba.	=	L. de Ball.	Cr.	=	H. Corder.
Bar.	=	E. E. Barnard.	Cs.	=	J. Comas Solá.
Be.	=	E. S. Beaven.	D.	=	F. C. Dennett.
Bg.	=	John Browning.	Da.	=	G. T. Davis.
Bi.	=	J. Birmingham.	E.	=	T. G. Elger.
Bn.	=	L. Brenner.	Es.	=	E. Essam.
Br.	=	T. Bredichin.	F.	=	P. Fauth.
Bt.	=	J. Brett.	Fe.	=	— Ferguson.
Bu.	=	T. H. Buffham.	Fo.	=	T. H. Foulkes.
Bw.	=	J. Brown.	Fr.	=	W. S. Franks.
By.	=	— Brindley.	G.	=	F. von P. Gruithuisen.
C.	=	G. Calver.	Ge.	=	S. M. B. Gemmill.

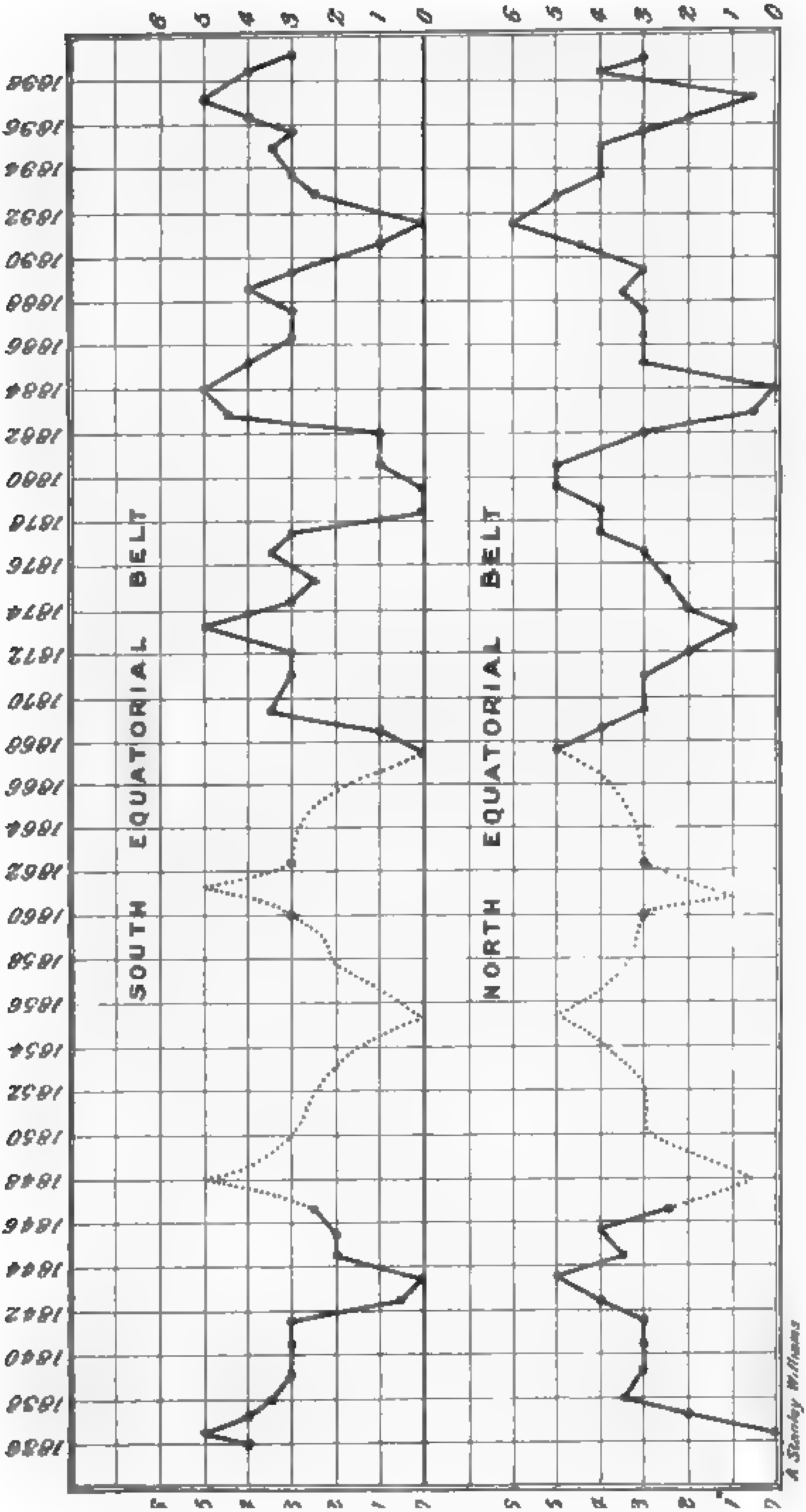
* This value is certainly too high. It is based upon six observations made by the writer alone, and about this time his estimates were generally considerably higher than those of other observers. Thus, in 1887 they were one above, in 1889 one above, and in 1890 two degrees of the scale above the values of the other observers. The value plotted upon the diagram accompanying this paper is 4.

Abbreviations—continued.

Gf.	= H. F Griffiths.	Mg.	= E. Mengering.
Gl.	= J. Gledhill.	Mi.	= A. F. Miller.
Gn.	= W. Godden.	My.	= K. Myez.
Go.	= W. Goodacre.	N.	= L. Niesten.
Gr.	= N. E. Green.	Ni.	= A. A. Nijland.
Gro.	= C. Grover.	O.	= J. M. Offord.
Gt.	= — von Gothard.	P.	= T. E. R. Phillips.
Gy.	= T. P Gray.	Pe.	= T. Perkins
H.	= W. J. Hall.	Pr.	= C. W. Pritchett.
He.	= A. Henderson.	Q.	= F. Quénisset.
Hi.	= G. D. Hirst.	R.	= J. Rheden.
Hl.	= A. S. Herschel.	Rd.	= — Ringwood.
Ho.	= E. S. Holden.	Ri.	= A. Riccò.
Hs.	= E. Holmes.	Rl.	= H. C. Russell.
J.	= W E. Jackson.	Ry.	= R. J Ryle.
K.	= J. E. Keeler.	S.	= J. H. Schroeter.
Ke.	= P. H. Kempthorne.	Sa.	= E. Salter.
Ki.	= R. Killip.	Sc.	= H. Schwabe.
Kl.	= H. J Klein.	Sh.	= C. F Smith.
Kn.	= E. B. Knobel.	Sm.	= D. Smart.
Kt.	= G. Knott.	T.	= F. Terby.
L.	= O. Lohse.	Td.	= C. Todd.
La.	= W. Lassell.	To.	= H. J. Townsend.
Le.	= R. G. Leigh.	W.	= A. S. Williams.
M.	= H. MacEwen.	Wa.	= W. R. Waugh.
Ma.	= A. M. Mayer.	We.	= T. W. Webb.
Me.	= J. Meller.	Wh.	= Mary M. Whitney.

The results contained in the preceding table have been laid down upon the accompanying diagram (see Plate 8), in which the horizontal lines represent degrees of redness according to the adopted scale. This diagram shows clearly the very striking variations in the redness of the two belts. The maxima and minima, it will be observed, are particularly well marked, and it is remarkable how the maximum redness of one belt always synchronises almost exactly with the minimum redness of the other. The range of variation is in reality even greater than that shown by the diagram, since at the time of minimum most observers describe the belts as appearing distinctly bluish, whereas both in the diagram and the table no account has been taken of this bluish tinge. The degree of redness at the times of maximum is also probably underrated, since there are usually some observers who notice the red colour at such times, but who are relatively deficient in colour perception. In some maxima, at least, the red colour has certainly been little inferior in intensity to that of the red spot when at its reddest. The belts at such times bear considerable resemblance to a bar of red-hot iron.

Where the observers are so numerous, there is naturally some diversity at times in the exact tints or degree of redness. This is more especially the case in the intermediate stages, when the red colour is not very deep. But at the times of maxima and minima the colours are so pronounced and strikingly contrasted that the observers are then practically all in agreement. There are a



COLOUR CHANGES OF JUPITER'S BELTS.

few instances of observers being apparently deficient in colour perception, and one or two cases which are suggestive of colour blindness.

As already stated, the time of maximum redness of one belt corresponds to the minimum of the other. The diagram shows that this correspondence is so exact that for the purpose of computing the period of variation it will be sufficient for all practical purposes to consider the variations of one belt only. There are eight observed maxima and minima, the times of which are given below.

Observed Times of Maxima and Minima.

N. Equat. Belt.		S. Equat. Belt.
Minimum	1836·36	Maximum
Maximum	1843·50	Minimum
Maximum	1867·70	Minimum
Minimum	1873·22	Maximum
Maximum	1879·72	Minimum
Minimum	1884·03	Maximum
Maximum	1891·72	Minimum
Minimum	1897·25	Maximum

These are the times corresponding to the extreme variations as actually observed, as it is doubtful whether any improvement in these times would result from consideration of the form of the colour curve. In a few cases, where there is a slight difference between the times for the two belts, the mean of the two has been taken.

From the four observed minima of the north equatorial belt the mean period of variation, derived by the method of least squares, is 12·14 years; and from the four maxima the mean period is 12·03 years, with the following residuals C−O in each case.

Minima. Years.	Maxima. Years.
−0·07	+0·09
−0·51	−0·05
+0·82	−0·04
−0·26	−0·01

The mean of these two values is 12·08 years. According to Professor Young's *General Astronomy* the length of a sidereal revolution of *Jupiter* is 11·86 years. The above mean period of variation agrees so closely with this that it is probable, or at least possible, that in the long run the two exactly correspond. If future observation should show that this is actually the case, it would seem that the variation in colour is a seasonal phenomenon,*

* At present the colourless, or bluish, phase of a belt occurs a short time after the autumnal equinox of the hemisphere in which such belt is situated.

and that the solar influence upon the changes which we observe upon the surface of *Jupiter* is greater than has been generally supposed, notwithstanding the distance of the planet from the Sun and the small inclination of the plane of its equator to the plane of its orbit. It seems certain, however, that the variation in colour can have no relation to the Sun-spot period, as was at one time thought might be the case with regard to the changes of colour of the bright equatorial zone. It should be mentioned here that the colour changes observed by Mr. John Browning and others in 1869-72 are quite distinct from those investigated in this paper. The former related to the bright central zone comprised within the two dark equatorial belts, whilst the latter refer to the changes in colour of the two last mentioned dark belts. The interesting subject of the relationship of the colour changes of the other dark belts and bright zones to those now under consideration has not yet been fully worked out. It may be mentioned, however, that the variations in the intensity of the colour of the red spot may possibly have some connection with the changes of the two equatorial belts. The red spot was near a maximum of redness in 1879-80, and there were minor maxima in 1886 and 1892. In 1897 there was also perhaps a feeble temporary increase in redness. All these times nearly correspond to a maximum redness of one or other of the two equatorial belts. In 1873, also, the reddish colour of the spot attracted particular notice at Lord Rosse's Observatory. The peculiar "tawny" hue, which sometimes characterises the bright equatorial zone,* seems to occur chiefly at the intermediate phases, when both the equatorial belts are moderately red.

The results of the present investigation may be shortly summarised as under :—

(1). The S. equatorial belt varies in redness periodically, the period of a complete change being 12·08 years.

(2). The N. equatorial belt undergoes a similar periodical variation in colour, and in the same period.

(3). The variations are so related that when the S. equatorial belt is at a maximum of redness the N. equatorial belt is at a minimum, and *vice versa*.

(4). The formulæ for finding the times of maxima and minima are :—

$$\left.\begin{array}{l}\text{Min. redness of S. Equat. Belt}\\ \text{Max. redness of N. Equat. Belt}\end{array}\right\} = \overset{\text{Years}}{1867{\cdot}65} + 12{\cdot}08E.$$

$$\left.\begin{array}{l}\text{Max. redness of S. Equat. Belt}\\ \text{Min. redness of N. Equat. Belt}\end{array}\right\} = \overset{\text{Years.}}{1872{\cdot}71} + 12{\cdot}08E.$$

(5). The interval from maximum redness of the N. equatorial belt to a minimum is a little shorter than the interval from

* Visible at the present time, and also last year.

minimum to maximum. The opposite is the case with regard to the other belt.

Computed times of maxima and minima.

N. Equat. Belt.		S. Equat. Belt.
Maximum	1903·88	Minimum
Minimum	1908·95	Maximum
Maximum	1915·97	Minimum

Addendum.

The reality of these periodical changes of colour will be apparent to anyone who will take the trouble to consult some of the authorities quoted in the last column of the table of the mean redness of the belts. The *coloured* drawings referred to in the following list will, however, show this at a glance. In 1879 the drawings by Professor T. Bredichin published in the *Bulletin de la Société Impériale des Naturalistes de Moscou*, Année 1879, Part 2, p. 370, and in the *Annales de l'Observatoire de Moscou*, vol. vi., p. 95, show the N. equatorial belt ruddy and the S. equatorial belt bluish (or greenish). The drawings by Dr. F. Terby, published in the *Bulletin de l'Académie Royale de Belgique*, 2^me série, tome xlix., No. 3, show the N. equatorial belt of a very deep red colour, whilst the S. equatorial belt is colourless. A similar difference in tint is indicated by the photographs of *Jupiter* by Dr. Common, published in the *Observatory* for 1880 February. In these the ruddy N. equatorial belt is very dense and conspicuous, whilst the bluish S. equatorial belt is almost invisible, showing that photographically its light differed materially in intensity from that of the other belt. In 1884 the drawings by Dr. Terby, published in the *Mémoires Cour. et Mém. des Savants Etrangers, publiés par l'Académie Royale de Belgique*, tome xlix., show the S. equatorial belt very red, whilst the N. equatorial belt is colourless. The drawings made by the same observer in 1891 and published in the *Bulletin de l'Académie Royale de Belgique*, 3^e série, tome xxii., p. 378, show the N. equatorial belt red, whilst the S. equatorial belt is now again devoid of red colour. Last, but by no means least, the coloured drawings published in Gruithuisen's *Astronomisches Jahrbuch* for the year 1845 (vol. vi.), show a complete half cycle of changes, from a minimum of the N. equatorial belt and maximum of the S. equatorial belt, to a maximum of the N. equatorial belt and a minimum of the S. equatorial belt. There are also numerous other coloured drawings published showing both belts red coloured, and relating to the intermediate stages between the epochs of maxima and minima.

At the present time the belts are in one of these intermediate stages. Both belts are of a moderately deep red colour, and are nearly equally red; though the S. equatorial belt usually appears

distinctly a little redder than the N. equatorial belt. The next epoch of maximum and minimum will occur in 1903, and I venture to predict that in that year the N. equatorial belt will be intensely red, whilst the S. equatorial belt will then appear colourless, or even of a bluish tint.

Photographs of the Radiant of the Leonid Meteors, and Attempts to Photograph the Meteor Stream. By Isaac Roberts, D.Sc., F.R.S.

The part of the sky around the radiant point of the Leonid meteors was closely watched during the night of the 13th and morning of the 14th November last, and during an interval of absence of clouds four photographs were obtained, two with the 20-inch reflector, and two with the 5-inch lens camera.

Clouds overcast the sky until two o'clock on the morning of the 14th, and then clearness set in, which continued till day-break. During that interval the four photographs were taken—two with simultaneous exposures of two hours, and two with ninety minutes'.

Only two Leonid meteors fell during the three and a half hours' interval, and they did not become luminous within the range of the camera photo-field of $7\frac{1}{2}$ degrees radius from the radiant, and consequently they were not photographed, but their directions with reference to certain stars were determined by sight. No other interval was suitable for photographic work during the passing of the stream.

On examination of the plates two nebulæ were discovered in close proximity to the radiant; and the following are their co-ordinates as deduced from the star *D.M.* No. 2164, zone 22° north, R.A. $9^h\ 54^m\ 44^s.4$, Dec. north 22° 39'.7, Epoch 1855. The nebulæ are in the positions R.A. $9^h\ 55^m\ 54^s.8$, Dec. north 22° 59'.4, and R.A. $9^h\ 55^m\ 54^s.8$, Dec. north 22° 58'.7.

The northernmost nebula is a well-defined star of about 13th magnitude, surrounded by a halo of faint nebulosity; and the other nebula, which is 42 seconds of arc south of it, resembles a star of about 16th magnitude, elongated nearly in *preceding* to *following* direction. These nebulæ are not referred to in the catalogues. I thought it possible that they were connected with the meteor stream, but another photograph taken on December 9 (25 days later) showed no change in their position, and therefore they could not be connected with the meteors.

Attempts to Photograph the Meteor Stream.

The Ephemeris of the denser part of the meteor stream which was prepared, under the directions of Dr. G. Johnstone Stoney and Dr. Downing, by Mr. Wright and other computers at the

office of the *Nautical Almanac*, and published in the *Monthly Notices* of this Society for 1898 November, enabled me to make fair trials in photographing the stream by aid of the 20-inch reflector and the 5-inch lens camera; and it was reasonable to expect that after the great care which had been taken in the preparation of the Ephemeris some practical results would be obtained.

Watchful vigilance was kept at my observatory for clear intervals in the sky between January 1 and March 10 (last month); but the sky had been abnormally covered with clouds and mistiness during the whole of the autumn and winter months. The moonlight also interfered with this kind of photographic work, and it was not till February 16 that the first suitable opportunity occurred to make a photographic trial with an exposure of ninety minutes. The plate when developed showed no indication of the meteors. The second opportunity occurred on March 5, when an exposure of two hours was made, but still there was no indication of the meteors. The third, and last, trial was made on March 10, when an exposure of four hours was obtained; but still there was no indication of the meteors; and if light of the feebleness of 17th to 18th magnitude stars had accompanied them, each of the photographs referred to would have shown it, for the conditions were favourable to photograph light up to that limit.

We all regret the absence of success in these experiments; but they were well worth the trouble and expense incurred in making the several trials during the past three years, and I do not regret having made the attempts.

The next important work that claims our attention in connection with this question is that of photographing the trails of the meteors as they pass through the Earth's atmosphere in November next; and although moonlight will to a considerable extent interfere, I think it probable that many trails will be bright enough to show through the effects of moonlight on the photographic plates. On this assumption I would offer the following suggestions:—

(1) We should take trial photographs, at favourable opportunities, between now and November, with the instruments and photo-plates we then propose to use.

(2) The photo-plates should be exposed separately in the camera, or telescope, during respective intervals of 5, 10, 15, 20, and 30 minutes, upon any part of the sky, with declination 23 degrees north. These experimental exposures should be made at those times which occur each month when the Moon will be about 135 degrees from the part of the sky here indicated, and when it is eleven days old. These conditions will roughly correspond with the lunar conditions that will prevail on November 14 next.

(3) The experimental plates should be developed till the films show a decided darkening by the effect of the moonlit sky,

and thus we shall be able to determine the equation of the instruments and gain experience for our guidance before the critical time for action arrives. We shall be able to judge beforehand for what length of time we may safely continue the exposures of the plates in the camera during partial moonlight, without risk of spoiling them by over-exposure, and also save trouble and time in changing the plates at unnecessarily short intervals.

Observations of Planet (433) *Eros, and of Comet Tuttle, at the Radcliffe Observatory, Oxford.*

(*Communicated by the Radcliffe Observer.*)

The following observations were made with the 10-inch Barclay Equatorial, using the ring micrometer, with power 100.

Date.	G.M.T.	Local Sidereal Time.	Observer.	Planet or Comet *minus* Star (corrected for Refraction only). R.A.	N.P.D.	No. of Comps.	Apparent R.A. of Planet or Comet.	Parallax in R.A. p.	Log. $(p \times \Delta)$.	Apparent N.P.D. of Planet or Comet.	Parallax in N.P.D. q.	Log $(q \times \Delta)$.	Ref.
	h m s	h m s		s	′ ″		h m s	s		° ′ ″	″		
					Planet Eros.								
1898. Sept. 6	11 1 35	22 0 45	R.	−10·74	+0 11·28	11	20 49 7·18	+0·14	9·0526	96 19 20·1	9·32	0·8713	(*a*)
					Comet Tuttle.								
1899 Apr. 10	9 2 48	10 13 14	R.	−51·59	−5 49·25	6	3 32 17·61	+0·22	9·5843	69 18 55·5	3·91	0·8327	(*b*)

Observer's Remarks.

(*a*) Planet faint, estimated magnitude 11·5. Sky hazy.
(*b*) Comet excessively faint; altitude small. Observations very difficult.

Assumed Places of the Comparison Stars.

Ref.	Mean R.A.	Reduction to Appar. R.A.	Mean N.P.D.	Reduction to Appar. N.P.D.	Authority.
	h m s	s	° ′ ″	″	
(*a*)	20 49 13·56	+4·36	96 19 27·25	−18·43	Radcliffe Transit Circle observations, 1898 Sept. 10, 14.
(*b*)	3 33 8·28	+0·92	69 24 49·08	− 4·33	Mean of Berlin B (A.G.) 1084, and Greenwich (1880) 557.

In the computation of the parallaxes the adopted value of the Sun's mean horizontal parallax is 8″·85; and the geocentric distances, Δ, are taken from the *Astronomische Nachrichten*, Nos. 3517 and 3555.

Observer: R., Mr. W. H. Robinson.

Radcliffe Observatory, Oxford:
1899 *April* 13.

Further Observations of Comet Coddington (*c* 1898). By John Tebbutt.

Having now brought my observations of this comet to a close, I herewith, in accordance with my promise, forward to you my second, and last, series of positions. The whole work of the two series embraces 102 nights, from 1898 June 15, to 1899 February 15, 768 comparisons, and 137 comparison stars. The observations made on June 22, 26, 29, July 3, 5, 6, 21, August 19, September 7, 10, 30, October 18, November 2, December 11, January 6, 16, 30, and February 14, 15, were more or less unsatisfactory. The comparisons of September 10 were especially so, for three reasons. The difference of north polar distance of the two objects was so great that they were with difficulty embraced within the square bar-micrometer; secondly, the comet was almost in contact with a 9th magnitude star, and therefore rendered faint; and, thirdly, the second reappearances of the comparison star, and the first disappearances of the comet at the edges of the micrometer bars, were almost simultaneous. On January 16 I could not find the comet as a separate object, but I noticed that a star of the 9th magnitude, close to its ephemeris-position, appeared slightly nebulous as it disappeared and reappeared at the edges of the bars. This star, which is identical with No. 247 of Zone $-50°$ of the *Cape Photographic Durchmusterung*, was therefore observed for the comet. The adopted mean places of the comparison stars are throughout the means, with equal weights, from the catalogues cited. An error, however, exists in the determination of the mean R.A. of Star No. 19 in my former communication. The seconds should be $34^s{\cdot}89$ instead of $34^s{\cdot}78$, and the seconds of the apparent R.A. of the comet for July 5 will accordingly be $20^s{\cdot}02$.

Observations of Comet Coddington (c 1898).

Date, 1898 and 1899.	Windsor Mean Time.	Comet—Star. Δ R.A.	Comet—Star. Δ N.P.D.	No. of Comps.	Comet's Apparent R.A.	Comet's Apparent N.P.D.	Log. pΔ for R.A.	Log. pΔ for N.P.D.	Comp. Star.
	h m s	m s	′ ″		h m s	° ′ ″			
Oct. 31	8 15 48	+5 37·25	+ 1 47·3	4	15 7 23·14	168 47 1·6	0·353	0·625	93
Nov. 2	8 20 16	−3 37·35	+ 4 22·9	2	15 20 25·63	169 42 14·1	0·391	0·616	94
5	8 19 17	+3 25·12	− 6 3·2	5	15 44 38·45	171 2 43·2	0·463	0·562	95
10	7 50 36	−1 34·70	+ 0 51·1	3	16 45 41·36	173 2 36·5	0·607	0·123	96
14	8 53 39	−9 27·57	− 7 3·7	3	18 3 46·52	174 10 32·0	0·684	0·102	97
Dec. 1	8 46 5	−2 40·71	+ 6 5·8	5	23 23 37·80	169 35 55·7	0·146	n0·728	98
2	9 7 11	+8 26·14	− 6 26·8	5	23 31 50·90	169 1 31·1	0·173	n0·699	99
8	8 56 31	−0 37·16	− 3 13·0	8	0 8 43·30	165 25 29·5	9·979	n0·700	100
8	10 11 53	−0 21·63	− 5 15·9	8	0 8 58·83	165 23 26·6	0·161	n0·550	100
9	9 2 53	+9 44·66	− 0 36·8	4	0 13 28·13	164 47 37·7	9·980	n0·686	101
10	9 22 42	+4 54·07	− 5 28·6	8	0 17 57·55	164 9 2·4	0·018	n0·649	102
11	9 33 57	+4 3·18	− 5 17·7	6	0 22 9·93	163 30 21·8	0·029	n0·621	103
13	9 17 33	−1 48·30	+ 7 27·2	8	0 29 45·61	162 13 9·8	9·956	n0·636	104
29	9 7 21	+1 59·07	+ 4 17·6	6	1 12 10·18	151 37 5·5	9·791	n0·460	105
Jan. 1	8 50 5	−0 16·88	− 1 28·5	10	1 18 2·10	149 37 55·7	9·734	n0·450	106
2	9 3 20	+3 48·07	+ 1 7·6	6	...	...	9·766	n0·396	107
2	9 3 20	+4 6·35	+ 8 17·1	6	...	...	9·766	n0·396	108
3	8 51 56	−0 45·86	+10 4·5	6	...	...	9·734	n0·408	109
3	8 51 56	−2 24·94	− 0 5·3	6	...	...	9·734	n0·408	110
4	9 8 29	−6 50·07	+ 7 22·3	8	1 23 36·90	147 38 41·5	9·772	n0·335	111
6	9 5 14	−0 26·38	− 9 28·9	10	1 27 6·91	146 19 58·1	9·759	n0·297	112
7	8 57 3	−2 59·45	− 4 40·6	3	1 28 49·34	145 41 8·0	9·738	n0·301	113

Dates, 1898 and 1899.	Windsor Mean Time.	Comet—Star. Δ R.A.	Comet—Star. Δ N.P.D.	No. of Comps.	Comet's Apparent R.A.	Comet's Apparent N.P.D.	Log. pΔ for R.A.	Log. pΔ for N.P.D.	Comp. Star.
	h m s	m s	′ ″		h m s	° ′ ″			
Jan. 7	8 57 3	−7 10·55	+ 1 9·9	3	1 28 49·58	145 41 4·0	9·738	n0·301	114
9	9 24 41	−6 23·79	+ 7 36·8	10	1 32 12·78	144 22 37·0	9·790	n0·101	115
12	9 40 7	+3 10·49	+ 5 47·6	7	...	..	9·806	n9·773	116
12	9 40 7	−6 16·09	+ 8 11·5	7	1 37 6·33	142 26 42·2	9·806	n9·773	117
13	8 51 7	+8 9·21	+11 24·9	2	1 38 37·98	141 49 49·8	9·716	n0·140	118
14	9 19 33	+0 26·08	+ 2 5·5	10	1 40 13·85	141 11 12·8	9·769	n9·877	119
14	9 19 33	−1 55·50	− 8 14·7	10	1 40 13·92	141 11 11·8	9·769	n9·877	120
15	9 31 19	+4 7·20	+ 0 9·6	7	1 41 47·70	140 33 13·2	9·786	n9·609	121
15	9 31 19	−1 1·26	− 2 30·6	7	1 41 47·51	140 33 11·5	9·786	n9·609	122
15	9 31 19	−5 12·76	− 9 19·3	7	1 41 47·86	140 33 13·1	9·786	n9·609	123
16	9 27 35	+2 31·30	− 3 51·5	4	...	...	9·778	n9·558	124
30	9 0 17	+1 47·31	3 7·6	6	...	...	9·724	9·870	125
Feb. 1	9 11 19	+7 8·66	− 6 32·0	7	2 6 4·71	130 29 23·5	9·738	0·060	126
1	9 11 19	+6 57·91	− 7 23·2	7	2 6 5·08	130 29 22·6	9·738	0·060	127
2	9 10 48	+5 22·86	− 5 10·3	8	2 7 25·59	129 56 11·8	9·737	0·095	128
3	9 6 2	−6 31·68	− 3 12·7	6	2 8 45·89	129 23 25·5	9·731	0·102	129
3	9 6 2	−7 48·41	− 6 27·6	6	2 8 45·56	129 23 23·8	9·731	0·102	130
6	8 58 58	−7 11·84	− 0 38·8	6	2 12 44·54	127 46 48·8	9·722	0·161	131
6	8 58 58	−7 32·63	− 2 24·7	6	2 12 44·90	127 46 46·2	9·722	0·161	132
9	8 49 9	−4 6·46	− 7 51·1	7	2 16 40·05	126 12 40·9	9·711	0·200	133
10	8 38 32	+1 42·14	+ 7 28·6	10	2 17 56·73	125 42 4·3	9·698	0·180	134
13	9 33 38	−1 53·39	− 5 34·6	4	2 21 52·66	124 10 22·8	9·750	0·431	135
14	8 36 26	−2 52·27	+ 8 5·3	8	2 23 6·32	123 41 38·8	9·698	0·269	136
15	8 27 51	−3 31·78	+ 9 26·8	3	2 24 22·34	123 12 42·6	9·688	0·260	137

Mean Places of the Comparison Stars for the Beginning of the Year of Observation.

Comp. Star.	Mean R.A.	Red. to App. R.A.	Mean N.P.D.	Red. to App. N.P.D.	Authorities.
	h m s	s	° ′ ″	″	
93	15 1 44·04	+1·85	168 44 56·4	+17·9	Argent. Gen. Cat. 20477; Stone, 8214.
94	15 24 0·57	+2·41	169 37 33·5	+17·7	Gilliss' Cat. 1850, 10985.
95	15 41 10·48	+2·85	171 8 29·3	+17·1	Gilliss' Cat. 1850, 11203.
96	16 47 10·75	+5·31	173 1 29·9	+15·5	Gilliss' Cat. 1850, 12063.
97	18 13 5·03	+9·06	174 17 23·5	+12·2	Gilliss' Cat. 1850, 13100.
98	23 26 11·59	+6·92	169 29 55·2	− 5·3	Gilliss' Cat. 1850, 16397.
99	23 23 18·03	+6·73	169 8 3·1	− 5·2	Gilliss' Cat. 1850, 16376.
100	0 9 15·18	+5·28	165 28 49·2	− 6·7	Argent Gen. Cat. 139; Stone, 68.
101	0 3 38·30	+5·17	164 48 21·1	− 6·6	Argent. Gen. Cat. 45; Stone, 22.
102	0 12 58·47	+5·01	164 14 37·8	− 6·8	Gilliss' Cat. 1850, 104.
103	0 18 1·87	+4·88	163 35 46·4	− 6·9	Gilliss' Cat. 1850, 164.
104	0 31 29·30	+4·61	162 5 49·8	− 7·2	Argent. Gen. Cat. 534.
105	1 10 7·37	+3·74	151 32 55·6	− 7·7	Argent. Gen. Cat. 1170; Stone, 480; suspected double.
106	1 18 17·63	+1·35	149 39 13·0	+11·2	Argent. Gen. Cat. 1312; Stone, 534.
107	1 16 7	+1·29	148 56	+11·2	Equatorial. 9½ mag.
108	1 15 49	+1·29	148 49	+11·1	Equatorial. 9½ mag.
109	1 22 29	+1·31	148 8	+11·0	Equatorial. 9½ mag.
110	1 24 8	+1·32	148 18	+11·1	Equatorial. 9½ mag.
111	1 30 25·64	+1·33	147 31 8·2	+11·0	Argent. Gen. Cat. 1536; Stone, 627.
112	1 27 32·05	+1·24	146 29 16·1	+10·9	Argent. Gen. Cat. 1479.
113	1 31 47·55	+1·24	145 45 37·8	+10·8	Argent. Gen. Cat. 1559; Stone, 637.
114	1 35 58·85	+1·28	145 39 43·3	+10·8	Argent. Gen. Cat. 1635; Stone, 669.
115	1 38 35·34	+1·23	144 14 49·6	+10·6	Argent. Gen. Cat. 1681; Stone, 683.
116	1 33 55	+1·12	142 21	+10·3	Equatorial. 8½ mag.
117	1 43 21·24	+1·18	142 18 20·3	+10·4	Argent. Gen. Cat. 1759; Stone, 711.
118	1 30 27·70	+1·07	141 38 14·7	+10·2	Argent. Gen. Cat. 1534.
119	1 39 46·66	+1·11	141 8 57·1	+10·2	Argent. Gen. Cat. 1696; Stone, 686.
120	1 42 8·30	+1·12	141 19 16·3	+10·2	Argent. Gen. Cat. 1733; Stone, 702.

Comp. Star.	Mean R.A.	Red. to App. R.A.	Mean N.P.D.	Red. to App. N.P.D.	Authorities.
	h m s	s	° ′ ″	″	
121	1 37 39·43	+1·07	140 32 53·5	+10·1	Argent. Gen. Cat. 1665; Stone, 677.
122	1 42 47·67	+1·10	140 35 32·0	+10·1	Argent. Gen. Cat. 1746.
123	1 46 59·49	+1·13	140 42 22·2	+10·2	Argent. Gen. Cat. 1816. Stone, 738.
124	1 40 45	+1·07	140 0	+10·0	Equatorial. 9 mag. = Cape Phot. Durch −50°.239.
125	2 1 34	+0·93	131 39	+ 8·7	Equatorial. 8½ mag. = Cape Phot. Durch −41°.192.
126	1 58 55·17	+0·88	130 35 47·2	+ 8·3	Argent. Gen. Cat. 2046.
127	1 59 6·29	+0·88	130 36 37·5	+ 8·3	Argent. Gen. Cat. 2053.
128	2 2 1·85	+0·88	130 1 13·8	+ 8·3	Argent. Gen. Cat. 2110; Stone, 835.
129	2 15 16·63	+0·94	129 26 29·7	+ 8·5	Argent. Gen. Cat. 2377; Stone, 926.
130	2 16 33·02	+0·95	129 29 42·9	+ 8·5	Argent. Gen. Cat. 2406.
131	2 19 55·46	+0·92	127 47 19·4	+ 8·2	Argent. Gen. Cat. 2485.*
132	2 20 16·61	+0·92	127 49 2·7	+ 8·2	Argent. Gen. Cat. 2489; Stone, 959
133	2 20 45·63	+0·88	126 20 24·2	+ 7·8	Argent. Gen. Cat. 2506.
134	2 16 13·74	+0·85	125 34 28·2	+ 7·5	Argent. Gen. Cat. 2399.
135	2 23 45·21	+0·84	124 15 49·5	+ 7·3	Argent. Gen. Cat. 2565; Stone, 981; Radcliffe, 1890, 577.
136	2 25 57·75	+0·84	123 33 26·3	+ 7·2	Argent. Gen. Cat. 2617 Stone, 999.
137	2 27 53·28	+0·84	123 3 8·7	+ 7·1	Yarnall, 1165; Argent. Gen. Cat. 2657.

Observatory: Peninsula, Windsor,
New South Wales, 1899 Feb. 27.

Observation of Tuttle's Comet (b 1899) made with the 30-inch Reflector of the Thompson Equatorial at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

On March 14 a photograph of *Tuttle's* Periodical Comet was obtained with the 30-inch reflector, with exposures of 10^m and 6^m. The positions of the comet and of eight comparison stars, as shown by the 10^m exposure, were measured, and the following place of the comet was obtained :—

Date.	G.M.T.	Apparent R.A.	Apparent Decl.	Log Δ.	Corr. for Parallax R.A.	Corr. for Parallax Decl.
	d h m s	h m s	° ′ ″		s	″
Mar.	14 7 37 17	1 50 19·23	+29 31 41·4	0·2480	+0·24	+3·1

Observations of Planet Eros from Photographs taken with the 30-inch Reflector of the Thompson Equatorial at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

Photographs of planet *Eros*, on which the position of the planet is shown with sufficient distinctness for accurate measurement, have been obtained with the 30-inch reflector on twenty-four nights between 1898 September 20 and 1899 March 31. Ilford "special rapid" plates were used, and the exposure usually given was five or six minutes. On twelve nights two exposures were made on the same plate, and on six nights two separate plates were obtained. On two nights (February 28 and March 14) short exposures of 40 seconds were also given, in order to obtain smaller images of the "reference stars" for use in determining the plate constants. In the later photographs the electric hand control was used to correct the large motion of the planet in right ascension, as the trail of the planet was too faint to be distinctly measurable when the equatorial was driven at a sidereal rate.

Réseaux have been printed on all the photographs except those taken on September 20, 21, 23, and October 3, and rectangular coordinates of the planet and of the reference stars have been measured in exactly the same way as for the astrographic photographs. The positions of the reference stars have been derived when possible from the catalogues of the *Astronomische Gesellschaft*, those between 5° and 15° N. having been kindly supplied in manuscript by Dr. Bruns, the Director of the Leipzig Observatory, and those south of the Equator from the Ottakring Zone Observations for *A.G.C.*, the Karlsruhe Observations, the Radcliffe Catalogue, 1890, and Schjellerup's Catalogue for 1865.

The images of the stars at some distance from the centre of the field show considerable *coma* away from the centre. This introduces some uncertainty as to the position of the optical centre of the images, and it was therefore necessary to examine the distortion of the field. For this purpose a plate was exposed four times on the *Pleiades* showing two lines of stars in the directions of the diagonals with displacement between, so that a star at the corner of the plate for one exposure was brought to the centre of the plate for another, and conversely, as indicated in the diagram, and the distances between the two images of a number of stars nearly in the same straight line were measured. These measures showed that, though there might be a distortion amounting to 2″ at a distance of 1° from the centre, the different magnitudes of the stars and consequent difference in the

images made it impracticable to obtain a trustworthy correction to the measures depending on the distance from the centre of the plate.

The coordinates of the reference stars were measured in two positions of the plate (in the second position turned in its own plane through 180°), and where there were two exposures the two images were measured by separate measurers and the mean taken. The planet's image or images were measured twice, in direct and reversed positions of the plate.

The measured coordinates of the reference stars were compared with the standard coordinates derived from their right ascensions and declinations, and linear corrections

$$ax+by+c \text{ and } dx+ey+f$$

were obtained to the measured coordinates. These corrections were applied to the measured coordinates of the planet, and its apparent right ascension and declination deduced. The constants c and f are arbitrary, depending on the assumed right ascension and declination of the centre of the plate in the computation of the standard coordinates; but a and e, when corrected for differential refraction and aberration, give the *scale* value, while d and e, similarly corrected, give the orientation.

The values of the correction to the scale (assumed to be 1^{mm} to $1'$) as derived from the separate determinations of a and e for each plate, and the corrections for orientation of each plate expressed in circular measure ($=-b=d$) are given in Table I.

The mean of thirty-two determinations from a gives ·01109 as the correction to the assumed scale, while the mean of the thirty-two determinations from e gives ·01117. The resulting

focal length is $(1 + \cdot 0111)^{mm} \times \text{cosec } 1'$, that is $3^m \cdot 4760$, or 11 feet 4·85 inches. The scale is almost exactly $\frac{1}{90}$th larger than the scale of 1^{mm} to $1'$ adopted for the Astrographic Chart.

The discordances between the two determinations of scale value and of orientation from the measures in the two directions x and y are exhibited in the fourth and seventh columns of Table I. The mean values of these discordances are $\pm \cdot 00028$ and $\pm \cdot 00039$ ($= \pm 1'' \cdot 3$). The large values of the discordances in the orientation as determined from the measures in the two directions shown on the plates taken on September 20, 21, 23, and October 3, is probably due to the fact that no *réseau* was printed on these plates, and their measurement was consequently more difficult.

On February 28 and March 14, in addition to exposures of five and six minutes, which showed the planet, an additional short exposure of forty seconds was also given. The plate constants were determined separately for the long and short exposures, and the differences of the coordinates of a number of stars near the centre of the plate were also measured. Thus a comparison was obtainable between the plate constants determined in the two ways. The following table shows satisfactory accordance between the results :—

	$a-a'$	$b-b'$	$c-c'$	$d-d'$	$e-e'$	$f-f'$
Feb. 28	$-\cdot 00024$	$-\cdot 00015$	$+\stackrel{''}{\cdot 03}$	$-\cdot 00009$	$-\cdot 00034$	$+\stackrel{''}{\cdot 27}$
Mar. 14	$-\cdot 00003$	$-\cdot 00004$	$-\cdot 18$	$-\cdot 00012$	$-\cdot 00015$	$+\cdot 09$

Table II. gives the lengths of the exposures on the different nights, the number of reference stars used, the mean discordances of the measured coordinates corrected linearly, and the "standard coordinates" derived from the tabular places of these stars. In addition the approximate coordinates of the planet and of the mean of the reference stars are also given.

Comparison of columns 3 and 4 with 5 and 6 shows that the position of the planet on the plate is never far from the mean of the stars. Any errors in the scale and orientation will only have a small effect on the determination of the "standard coordinates" (and therefore of the deduced right ascension and declination) of the planet.

The mean values of the discordances shown in columns 8 and 9 of Table II. are $\pm^s \cdot 061$ and $\pm 0'' \cdot 76$. These represent the combined effect of errors in the measures (including distortion) and in the tabular places of the stars. As the average number of reference stars is 16 per plate, and the planet is near their mean position, the probable error of its position arising from these causes is $\pm^s \cdot 013$ and $\pm'' \cdot 16$.

Table I.

Plate Constants.

Date.	Correction to Scale Value. *a*	*e*	*a*−*e* (in units of fifth decimal place)	Correction for Orientation. *b*	*d*	*b*+*d* (in units of fifth decimal place)
1898.						
Sept. 20	−·01048	−·01099	+51	+·00931	−·00801	+130
21	−·01106	−·01120	+14	+·00055	+·00063	+118
23	−·01103	−·01124	+22	−·00260	+·00391	+131
Oct. 3	−·01099	−·01120	+21	−·00087	+·00207	+120
Nov. 3	−·01122	·01063	−59	−·01117	+·01061	−56
Dec 7	−·01080	−·01113	+33	−·01426	+·01369	−57
9	−·01072	−·01112	+40	−·01107	+·01083	−24
1899.						
Jan. 10	−·01123	−·01139	+16	−·01444	+·01438	−6
25	−·01166	−·01098	−68	−·01595	+·01606	+11
26	−·01060	−·01083	+23	−·01498	+·01498	0
27	−·01140	−·01142	+2	−·01469	+·01415	−54
Feb. 2	−·01102	−·01144	+42	−·01279	+·01233	−46
22	−·01137	−·01128	−9	−·00842	+·00858	+16
22	−·01152	−·01156	+4	−·01396	+·01408	+12
24	−·01105	−·01102	−3	−·01374	+·01351	−23
24	−·01120	−·01095	−25	−·01436	+·01437	+1
25	−·01129	−·01107	−22	−·01519	+·01500	−19
27	−·01116	−·01126	+10	−·01602	+·01675	+73
27	−·01118	−·01122	+4	−·01448	+·01483	+35
28	−·01142	−·01159	+17	−·01588	+·01533	−55
28	−·01118	−·01125	+7	−·01573	+·01542	−31
Mar. 5	−·01157	−·01110	−47	−·01165	+·01143	−22
[illegible]	−·01148	−·01121	−27	−·01435	+·01420	−15
9	−·01096	−·01152	+56	·01833	+·01848	+15
11	−·01062	−·01134	+72	−·01565	+·01619	+54
14	−·01066	−·01112	+46	−·01564	+·01591	+27
14	−·01064	−·01098	+34	−·01560	+·01603	+43
24	−·01077	−·01098	+21	−·02005	+·01999	−6
24	−·01085	−·01095	+10	−·01292	+·01277	−15
27	−·01118	−·01093	−25	−·01493	+·01492	−1
27	−·01126	−·01108	−18	−·01647	+·01664	+17
31	−·01128	−·01093	−35	−·01560	+·01564	+4
Mean	−·01109	−·01115	±28	...	...	±39

TABLE II.

Date.		Exposure.	Approx. Coords. of Planet. R.A.	Approx. Coords. of Planet. Decl.	Approx. Coords. of Mean of Reference Stars. R.A.	Approx. Coords. of Mean of Reference Stars. Decl.	No. of Stars.	Mean discordance of tabular and measured Coords. R.A.	Mean discordance of tabular and measured Coords. Decl.
1898.			′	′	′	′		s	″
Sept.	20	20ᵐ	− 0·1	− 1·3	− 11·0	+ 0·2	14	± ·046	± 0·51
	21	20ᵐ	− 2·0	+ 3·5	− 8·5	+ 4·0	15	± ·060	± 0·66
	23	15ᵐ	− 0·4	− 2·1	0·0	− 1·4	16	± ·044	± 0·60
Oct.	3	10ᵐ & 5ᵐ	+ 4·5	− 2·0	+ 10·5	+ 0·3	16	± ·044	± 0·66
Nov.	3	20ᵐ	+ 19·7	+ 2·3	− 4·2	− 12·2	7	± ·038	± 0·51
Dec.	7	5ᵐ & 7ᵐ	− 7·5	− 1·5	+ 4·0	− 12·5	8	± ·044	± 0·57
	9	5ᵐ & 6ᵐ	− 7·8	− 15·2	+ 0·6	− 14·3	10	± ·054	± 0·90
1899. Jan.	10	5ᵐ & 4ᵐ	− 3·6	+ 1·2	− 0·4	+ 1·4	22	± ·050	± 0·66
	25	4ᵐ & 6ᵐ	− 3·8	+ 3·2	− 20·3	0·0	13	± ·101	± 0·75
	26	4ᵐ & 6ᵐ	− 4·1	+ 2·2	+ 4·2	+ 1·6	15	± ·062	± 0·63
	27	4ᵐ & 6ᵐ	− 7·5	+ 0·6	+ 2·3	+ 13·4	14	± ·067	± 0·51
Feb.	2	4ᵐ & 6ᵐ	− 10·6	+ 3·0	− 13·4	+ 2·0	18	± ·051	± 0·69
	22	5ᵐ	− 5·3	+ 4·5	+ 1·5	+ 2·4	15	± ·097	± 0·84
	22	5ᵐ	− 7·0	+ 2·5	− 0·6	+ 0·3	15	± ·072	± 0·87
	24	4ᵐ	− 2·4	+ 2·0	− 1·9	− 8·4	22	± ·079	± 0·54
	24	4½ᵐ	− 2·5	+ 3·2	− 1·2	− 10·9	21	± ·062	± 0·69
	25	5ᵐ	− 3·8	+ 4·3	+ 6·6	− 9·6	23	± ·087	± 0·81
	27	5ᵐ	− 5·4	+ 2·7	+ 3·0	+ 6·7	14	± ·087	± 1·17
	27	6ᵐ	+ 1·8	+ 3·8	+ 7·7	− 0·6	14	± ·068	± 0·81
	28	6ᵐ & 5ᵐ	− 3·3	+ 1·6	+ 1·7	+ 4·8	14	± ·075	± 1·17
	28	40ˢ	...	...	+ 1·4	+ 3·7	14	± ·068	± 0·81
Mar.	5	5ᵐ	+ 2·7	+ 1·2	+ 0·2	− 8·3	19	± ·065	± 1·26
	5	6ᵐ	+ 2·7	+ 1·9	− 0·1	− 7·6	19	± ·067	± 1·35
	9	6ᵐ & 5ᵐ	+ 0·9	− 6·4	− 3·2	+ 22·4	9	± ·078	± 0·75
	11	6ᵐ & 5ᵐ	− 7·6	− 9·4	+ 0·5	− 4·4	11	± ·053	± 0·42
	14	5ᵐ & 4ᵐ	+ 1·4	+ 1·9	+ 13·2	+ 5·4	17	± ·058	± 0·87
	14	40ˢ	...	...	+ 13·2	+ 4·4	17	± ·058	± 1·08
	24	5ᵐ	+ 3·2	+ 3·4	+ 5·3	− 17·5	18	± ·056	± 0·51
	24	5ᵐ	+ 1·3	+ 2·5	+ 5·6	− 16·4	17	± ·036	± 0·57
	27	5ᵐ	− 4·8	+ 3·1	+ 6·2	+ 4·1	21	± ·038	± 0·78
	27	6ᵐ	− 8·5	+ 1·0	+ 2·0	+ 2·0	21	± ·056	± 0·81
	31	6ᵐ	− 8·8	+ 2·5	+ 4·0	+ 4·8	16	± ·041	± 0·66
							Mean	± ·061	± 0·76

The right ascensions and declinations of the planet and the mean times of observation are given in Table III.

TABLE III.

Date.	G.M.T.	Apparent R.A.	Apparent Decl.	Log. Δ.	Corr. for Parx. R.A.	Corr. for Parx. Decl.
	h m s	h m s	° ′ ″		s	″
Sept. 20	9 20 6	20 37 32·39	− 6 21 20·8	9·9400	+0·08	+8·6
21	8 39 17	20 37 7·68	− 6 21 12·3	9·9430	+0·01	+8·5
23	7 49 1	20 36 26·32	− 6 20 43·7	9·9492	−0·07	+8·4
Oct. 3	7 58 14	20 35 59·57	− 6 13 59·5	9·9811	+0·02	+7·8
Nov. 3	8 15 36	21 1 4·39	− 4 47 51·2	0·0747	+0·16	+6·1
Dec. 7	6 39 44	21 58 19·74	− 0 49 25·7	0·1429	+0·12	+5·0
9	5 24 41	22 2 15·07	− 0 30 56·4	0·1464	+0·04	+5·0
Jan. 10	6 11 27	23 14 30·46	+ 5 39 3·0	0·1890	+0·14	+4·2
25	6 19 43	23 53 9·29	+ 9 5 51·6	0·2015	+0·15	+3·9
26	6 5 49	23 55 49·01	+ 9 19 57·6	0·2021	+0·15	+3·8
27	6 22 33	23 58 33·08	+ 9 34 25·6	0·2029	+0·16	+3·8
Feb. 2	6 9 36	0 15 2·42	+11 0 43·9	0·2066	+0·15	+3·7
22	7 0 19	1 14 18·37	+15 49 2·4	0·2152	+0·20	+3·6
22	7 13 28	1 14 20·10	+15 49 9·5	0·2152	+0·21	+3·6
24	6 51 8	1 20 34·05	+16 16 46·8	0·2158	+0·20	+3·5
24	7 4 51	1 20 35·87	+16 16 53·7	0·2158	+0·20	+3·6
25	7 38 59	1 23 50·45	+16 31 1·2	0·2161	+0·22	+3·7
27	8 3 29	1 30 17·37	+16 58 34·6	0·2166	+0·23	+3·8
27	8 16 2	1 30 18·75	+16 58 39·9	0·2166	0·23	+3·8
[illegible]	7 5 49	1 33 22·61	+17 11 32·2	0·2168	+0·21	+3·5
28	7 5 49	1 33 22·61	+17 11 31·9	0·2168	+0·21	+3·5
Mar. 5	7 33 8	1 49 48·90	+18 17 41·4	0·2179	+0·22	+3·6
5	7 44 34	1 49 50·47	+18 17 47·2	0·2179	+0·22	+3·6
9	7 12 14	2 3 11·73	+19 7 54·0	0·2188	+0·21	+3·5
[illegible]	7 16 32	2 10 1·79	+19 32 13·4	0·2192	+0·22	+3·5
14	7 20 22	2 20 24·73	+20 7 24·9	0·2197	+0·22	+3·5
14	7 20 22	2 20 24·75	+20 7 24·7	0·2197	+0·22	+3·5
24	7 37 43	2 56 11·46	+21 51 42·1	0·2213	+0·23	+3·5
24	7 48 39	2 56 13·03	+21 51 46·3	0·2213	+0·23	+3·5
27	7 34 36	3 7 14·07	+22 18 23·8	0·2217	+0·23	+3·4
27	7 48 9	3 7 16·37	+22 18 27·4	0·2217	+0·23	+3·5
31	7 48 35	3 22 13·88	+22 50 19·9	0·2222	+0·23	+3·5

Indications of the accuracy of the above results may be obtained as follows :—

(i.) The observations from September 20 to December 9 have been given in the November, December and January numbers of the *Monthly Notices*. The results there given were obtained from an entirely different series of measures from those used in the present determination; in the earlier measures the point considered as the centre of an image of a star at some distance from the centre of the field was taken systematically nearer the *coma* than in the present measures. The differences between the two methods of measurement give the following differences of right ascension and declination:—

Date.	R.A.	Decl.
	s	″
1898 Sept. 20	−·04	−0·3
21	+·04	−0·2
23	+·01	+0·3
Oct. 3	+·12	−0·2
Nov. 3	+·14	+0·1
Dec. 7	−·01	−0·1
9	+·01	+1·1

(ii.) The differences between the positions obtained from two plates taken on the same night when correction is made for the movement of the planet in the interval are

Date.	R.A.	Decl.
	s	″
1899 Feb. 22	+·09	−0·3
24	+·02	−0·8
27	−·24	−1·5
Mar. 5	+·03	−0·3
24	−·09	0·0
27	(+·53)*	−0·6

(iii.) When the plate constants are determined from the subsidiary short exposure, and from the differences of the coordinates of the images of a number of stars near the centre, the differences between the determinations of the right ascensions and declination of the planet are

Date.	R.A.	Decl.
	s	″
1899 Feb. 28	0·00	−0·3
Mar. 14	+0·02	−0·2

In addition to the errors which would be shown in these comparisons, there may be systematic errors of the catalogues employed. No investigation has been made of these and no corrections have been applied; but in most cases these are probably small.

* The image of the planet was very faint on the second plate taken on March 27.

Results of Micrometer Measures of Double Stars made with the 28-inch Refractor at the Royal Observatory, Greenwich, in the years 1896, 1897, *and* 1898.

(Communicated by the Astronomer Royal.)

The measures were made with a bifilar position-micrometer on the 28-inch refractor, aperture 28 inches, focal length 28 feet The power generally used was 670, but when the definition permitted a power of 1030 was used for observing very close pairs. A blue glass shade was employed to diminish the light and irradiation when bright stars were observed. The observations were made in variously coloured fields or in a dark field with illuminated wires. The initials in the last column are those of the observers, viz. :—

D.	Mr.	Dyson.	C.	Mr.	Cowell.
L.	„	Lewis.	B.	„	Bryant.
W.B.	„	Bowyer.	D.E.	„	Edney.
P.M.	„	Melotte.	N.	„	Niblett.

Micrometric Observations of Double Stars.

Star's Name.		R.A. 1900. h	m	N.P.D. 1900. °	′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1890 +	Obs.
Σ 3062	..	0	1	32	10	339·2	1·42	1	6·9	8·0	8·978	B.
β 1014	..	0	2	58	53	304·1	1·15	3	7·0	12·5	7·937	L.
β 255	...	0	6	62	10	107·5	0·44	1	7·5	8·4	6·827	L.
						91·7	0·53	3	..		7·885	W.B.
						99·3	0·45	3	..		7·885	L.
OΣ 2	A B.	0	8	63	35	41·4	0·77	1	6·5	8·0	6·805	W.B.
						36·6	0·52	2	...		6·816	L.
						34·4	0·64	3	...		7·844	W.B.
						33·5	0·47	2	..		7·896	L.
						36·9	0·56	2	...		8·877	L.
						34·6	0·69	3	.		8·908	W.B.
h 1007 (OΣ A C.)		0	8	63	35	227·2	17·82	1	6·5	9·6	7·898	W.B.
						226·8	17·62	1	..		7·909	L.
						225·7	17·42	1	.		8·778	W.B.
						225·8	17·91	1	..		8·868	L.
OΣ 4	...	0	10	54	8	146·0	0·48	1	7·5	8·0	7·953	L.
						146·9	0·48	1	...		8·950	W.B.
β 1093		0	15	79	46	39·8	0·31	1	7·3	8·2	6·927	L.
						49·2	0·50	1	...		7·958	L.
						60·9	0·39	1	.		8·885	L.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1890+	Obs.
	h m	° ′	°	″				
β 1015 ...	0 15	78 16	116·4	0·40	1	8·4 8·6	7·860	W.B.
			112·6	0·46	1	...	7·936	L.
			124·0	0·48	3	...	8·864	W.B.
			118·1	0·51	1	...	8·890	L.
β 865 ...	0 38	47 20	192·0	1·48	1	8·3 8·8	8·950	W.B.
*	0 41	57 24	12·9	0·53	1	...	7·813	W.B.
Σ 60 (η Cass.)	0 42	32 44	215·3	5·04	1	4·0 7·6	8·104	B.
β 495 ...	0 43	71 52	222·2	0·57	1	7·5 7·7	6·805	W.B.
			221·3	0·81	1	...	6·955	L.
			218·8	0·68	1	...	7·827	W.B.
			219·7	0·62	2	...	7·874	L.
			220·3	0·85	3	...	8·817	W.B.
OΣ 20 (66 Pisc.)	0 49	71 21	332·8	0·40	1	6·0 6·4	6·934	L.
			325·5	0·51	1	...	7·860	W.B.
			330·2	0·42	3	...	7·885	L.
			327·6	0·60	1	...	8·890	L.
			322·0	0·50	2	...	8·949	W.B.
Σ 73 (36 Androm.)	0 50	66 55	13·0	1·17	3	6·2 6·8	6·839	W.B.
			14·1	1·28	1	...	6·857	D.
			16·2	0·92	2	...	7·863	W.B.
			17·8	1·12	2	...	7·896	L.
			16·4	1·04	2	...	8·794	W.B.
β 1228 ...	1 0	77 16	266·8	0·69	1	8·3 8·9	7·865	L.
			265·2	0·56	1	...	7·980	W.B.
			275·7	0·89	3	...	8·868	W.B.
β 303 ...	1 4	66 45	284·3	0·70	1	7·2 7·2	6·857	D.
			280·1	0·64	3	...	7·882	W.B.
			286·2	0·49	2	...	7·896	L.
			281·3	0·50	1	...	8·890	L.
			280·9	0·64	3	...	8·923	W.B.
Σ 113 (42 Ceti)	1 15	91 2	353·2	1·35	2	6·2 7·2	6·885	D.
			349·7	1·54	2	...	8·982	B.
β 506 (η Pisc.)	1 26	75 10	14·1	1·16	1	4·0 10·5	7·986	L.
β 999 A.B.	1 22	45 9	123·3	1·59	1	4·8 11·5	8·868	L.
C.D.	...	...	136·8	5·32	1	10·5 10·5	8·868	L.
β 507 ..	1 30	63 45	153·5	2·20	1	8·0 11·0	7·813	W.B.
			158·6	1·75	1	...	7·972	B.
			158·3	2·24	1	...	7·975	L.
... ...	...	...	158·9	1·56	1	...	8·868	L.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.		Epoch 1890+	Obs.
	h m	° ′	°	″					
Σ 138 ...	1 31	82 55	36·5	1·67	1	7·3	7·3	6·958	W.B.
			35·0	1·39	1	...		7·879	W.B.
			40·3	1·72	1	...		7·975	B.
			34·5	1·54	3	...		8·934	B.
Σ 157 A.C.	1 40	51 36	116·2	12·48	1	8·5	8·7	8·868	L.
Σ 158 ...	1 41	57 21	258·0	2·04	2	8·3	8·8	6·865	W.B.
			253·9	2·09	1	...		7·813	W.B.
			257·6	2·00	1	...		7·958	L.
			257·1	2·09	1	...		8·931	W.B.
			260·1	2·14	1	...		8·994	B.
β 1016 ...	1 43	57 27	22·6	0·47	1	8·7	8·7	7·860	W.B.
			22·5	0·46	2	...		7·947	L.
			28·3	0·60	1	...		8·931	W.B.
Hough. 311	1 45	66 0	184·2	0·42	1	7·5	7·5	7·827	W.B.
			184·7	0·49	1	...		8·843	W.B.
Σ 180 (γ Arietis)	1 48	71 12	360·2	8·38	1	4·2	4·4	6·882	L.
			358·3	8·32	1	...		7·865	L.
β 512	1 48	71 13	17·2	1·84	1	8·6	11·7	7·865	L.
*	1 49	71 17	65·7	6·13	1	9	10	7·865	L.
Σ 183 A.B.	1 49	61 46	360·3	...	1	7·5	8·2	6·931	W.B.
			362·6	0·49	1			7·827	W.B.
			358·8	0·47	1			7·882	L.
			364·5	0·56	3	...		8·014	W.B.
A.C.	..		161·7	5·63	1	7·5	8·7	7·827	W.B.
			167·9	5·24	1	...		7·882	L.
			163·8	5·57	3	...		8·914	W.B.
Σ 205 (γ[1] Androm.)	1 58	48 9	64·9	10·15	1	3·0	5·0	6·093	L.
			65·4	10·30	1	...		8·868	L.
OΣ 38 (γ[2] Androm.)	1 58	48 9	311·9	0·17	1	5·0	6·2	6·093	L.
			120·1	0·45	1	...		8·868	L.
Σ 208 (10 Arietis)	1 58	64 33	61·6	0·77	2	6·2	8·4	7·898	W.B.
			60·5	0·83	1	...		8·025	L.
			64·8	0·87	1	...		8·967	W.B.
			60·3	0·74	1	...		8·970	B.
Σ 228 ..	2 8	43 1	66·9	0·27	1	6·7	7·6	6·093	L.
OΣ 43 ...	2 35	63 49	224·5	0·87	1	8·5	9·5	6·099	L.
*	2 36	63 28	309·8	0·21	1	8·5	9·5	6·099	L.
			319·7	...	1	...		6·099	D.

Star's Name.		R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.		Epoch 1890+	Obs.
		h m	° ′	°	″					
OΣ 44	...	2 36	47 43	55·3	1·40	1	8	9	8·131	W.B.
				57·0	1·30	1	...		8·964	L.
β 262	...	2 42	59 22	245·6	1·35	1	8·2	9·6	6·846	W.B.
				242·3	1·50	4	...		7·890	W.B.
				247·2	...	1	...		8·976	W.B.
Σ 305	...	2 42	71 2	315·9	2·90	1	7·3	8·0	6·016	L.
				317·2	3·10	2	...		6·867	W.B.
				316·3	2·92	3	...		7·950	W.B.
				316·2	3·01	1	...		7·975	L.
				317·2	3·02	1	...		8·107	L.
				314·7	2·78	1	...		8·947	W.B.
				319·2	3·07	1	...		8·994	B.
β 524	A.B.	2 46	52 5	190·2	0·22	1	5·5	6·5	6·090	L.
Σ 318	A.C.	...	...	237·4	13·92	1	5·5	9·5	6·090	L.
β 525	...	2 53	68 47	134·4	0·33	3	7·5	7·5	6·658	L.
				132·6	0·29	4	...		7·908	L.
				127·3	0·30	3	...		8·103	L.
				131·0	0·40	1	...		8·953	B.
Σ 333 (ε Arietis)		2 53	69 4	202·1	1·34	1	5·7	6·0	6·077	L.
				200·6	1·33	1	...		[illegible]	L.
				203·8	1·22	3	...		8·928	B.
				202·3	1·16	1	...		8·931	W.B.
β 1030	...	3 4	68 40	161·7	0·48	2	8·5	8·5	6·517	L.
				162·6	0·53	2	...		7·896	L.
				159·9	0·42	1	...		8·107	L.
				154·2	0·48	1	...		8·121	W.B.
				161·7	0·53	1	...		8·953	B.
β 530	...	3 9	67 27	197·0	1·84	1	9·7	10·1	6·934	L.
				...	1·68	1	...		6·847	W.B.
				193·3	2·23	1	...		8·107	L.
β 84	...	3 11	96 18	17·8	0·57	1	6·8	7·3	8·025	B.
β 878	...	3 22	67 32	74·1	1·05	1	5·8	13·7	7·882	L.
Σ 412	A.B.	3 29	65 52	19·9	0·32	3	6·6	6·9	6·405	L.
				12·8	0·33	3	...		7·892	L.
	A.C.	3 29	65 52	61·0	22·21	1	6·6	9·0	7·882	L.
β 533	...	3 29	58 39	46·4	0·49	1	8·0	8·0	7·860	L.
				49·7	0·54	1	...		8·121	W.B.
				51·8	0·62	1	...		8·964	L.
				53·0	0·51	1	...		8·969	B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1890+	Obs.
	h m	° ′	°	″				
β 880 ...	3 38	58 9	349·2	0·40	1	8·4 8·4	8·121	W.B.
			346·9	0·42	1	...	8·969	L.
β 1184 ...	3 42	67 56	93·8	0·59	1	8·0 8·5	7·865	L.
			84·7	0·48	2	...	7·924	W.B.
			95·2	0·62	1	...	8·121	W.B.
OΣ 65 ...	3 44	64 43	203·3	0·57	1	5·5 6·5	6·099	L.
Σ 483 ...	3 57	50 40	322·7	0·49	1	8·0 9·5	6·099	L.
			303·0	...	1	...	8·104	B.
			306·7	0·63	2	...	8·964	L.
OΣ 531 ...	4 1	52 11	132·5	2·14	1	8·5 10·2	6·849	W.B.
			127·8	1·89	1	...	7·936	L.
			126·9	1·92	2	...	7·945	W.B.
			129·1	1·91	2	...	8·927	L.
			127·5	1·74	1	...	8·969	B.
Hough. 326	4 2	61 40	175·1	0·30	1	8·5 8·5	7·865	L.
			177·3	0·38	1	...	8·890	L.
β 1232 ...	4 2	61 11	353·2	0·36	1	8·5 9·5	6·093	L.
			358·0	0·15	1	...	8·890	L.
OΣ 79 ...	4 14	73 45	115·5	...	1	6·4 7·6	6·039	L.
OΣ 80 ...	4 17	47 47	179·1	0·67	1	6·5 7·0	8·964	L.
OΣ 82 ...	4 18	75 12	136·6	0·63	2	8·0 8·7	6·083	L.
			129·1	0·40	1	...	7·860	W.B.
β 1235 ...	4 18	67 29	46·2	0·35	1	8·4 8·5	6·093	L.
			65·4	0·34	1	...	8·121	W.B.
Σ 535 ...	4 18	78 51	336·9	0·96	1	6·7 8·2	6·115	D.
			329·7	1·42	2	...	7·442	W.B.
			322·5	1·50	1	...	8·947	W.B.
Hastings ...	4 30	70 29	45·2	0·49	1	8 9	8·131	W.B.
OΣ 86 ...	4 31	70 27	53·2	0·53	1	7·5 7·5	8·637	W.B.
Σ 567 ...	4 31	70 40	323·1	1·75	1	8·5 9·0	8·950	L.
Σ 572 ...	4 32	63 16	197·0	3·82	1	6·5 6·5	6·074	D.
			199·9	3·91	3	...	7·970	W.B.
			201·2	3·62	2	...	8·126	W.B.
			204·2	3·69	2	...	8·544	B.
β 883 A.B.	4 46	79 6	205·5	...	1	7·5 7·8	7·000	D.
			36·1	0·35	5	...	7·664	L.
			34·7	0·39	2	...	7·902	W.B.
			38·7	0·32	2	...	8·106	L.
			51·4	0·36	1	...	8·950	L.

Star's Name.		R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance	No. of Nights	Mags.	Epoch 1890+	Obs.
		h m	° ′	°	″				
β 883	A.C.	4 46	79 6	153·1	18·04	1	7·5 13	7·800	L.
				153·9	17·92	1	...	7·977	W.B.
β 552	...	4 46	76 31	191·7	0·48	1	6·9 10·2	7·975	L.
				188·1	0·43	1	...	8·052	L.
OΣ 98 (ι Orionis)		5 2	81 39	180·7	0·83	1	5·5 7·0	6·112	D.
				176·3	1·18	1	...	8·104	B.
				183·2	0·81	1	...	8·145	L.
Σ 645	A.C.	5 3	62 5	22·3	11·78	1	6·0 8·5	6·110	L.
				28·3	11·93	1	...	8·107	L.
β 1047	A.B.	5 3	62 5	50·3	0·21	1	8·5 8·8	6·110	L.
OΣ 100	...	5 5	81 57	251·2	4·29	1	...	8·093	B.
Σ 687	A.B.	5 15	56 17	68 9	17·57	2	8·1 8·6	8·192	L.
β 886	C.D.	5 15	56 17	258·2	0·82	2	9·1 9·6	8·197	L.
β 887	A.B.	5 16	56 40	198·0	0·91	1	8·9 9·7	8·249	L.
	A.C.	...	...	335·2	10·55	1	8·9 12	8·238	L.
Dawes 5 (η Orionis)		5 19	92 30	81·1	0·71	1	3·5 5·5	6·112	D.
				81·8	0·97	1	...	8·013	B.
Σ 728	...	5 26	84 7	176·3	0·32	1	5·5 6·5	6·131	L.
Σ 749	...	5 30	63 8	178·6	0·84	2	7·1 7·2	6·515	L.
				177·6	0·74	1	...	7·156	L.
				168 9	0·93	3	...	7·653	W.B.
				172·4	0·94	1	...	8·104	B.
				170·9	0·70	2	...	8·137	W.B.
* near Σ 749		...	...	287·8	4·43	1	...	7·006	W.B.
OΣ 112	...	5 33	52 6	75·6	...	1	7·5 7·5	8·121	W.B.
				72 6	0·70	1	...	8·238	L.
β 560	...	5 42	60 18	167·5	...	1	8·0 8·5	8·121	W.B.
				163 3	0·69	2	...	8·594	L.
OΣ 118	...	5 42	69 10	317·1	0·64	1	8·0 8·8	7·156	L.
				308·3	0·53	1	...	7·966	W.B.
				313·5	0·68	2	...	8·128	W.B.
Σ 799	...	5 45	51 31	183·6	1·01	1	7·0 8	7·156	L.
				176·5	0·82	1	...	8 104	B.
				178·6	0·75	2	...	8·126	W.B.
				179·2	0·80	1	...	8 238	L.
Σ 881	...	6 12	30 33	105·9	0·55	1	6·4 9·7	8·025	L.
Σ 888	...	6 14	61 31	251·8	2·73	2	7·5 9·2	8·594	L.
β 1021	...	6 25	61 33	77·0	0·66	1	8·1 9·4	8·238	L.
Σ 919	A.B.	6 25	96 57	132·4	7·29	1	5·0 5·5	8 953	B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1890+	Obs.
	h m	° ′	°	″				
Σ 919 B.C.	...	...	102·8	2·93	1	5·5 6·0	8·953	B.
OΣ 149 ...	6 30	62 38	282·0	0·63	2	7 9	8·238	L.
Σ 936 ...	6 30	31 48	266·5	1·99	1	7·0 8·7	7·934	W.B.
			266·4	1·52	2	...	8·042	L.
Σ 948 A.B.	6 37	30 27	121·8	1·64	1	5·2 6·1	8·025	L.
			119·5	1·60	1	...	8·969	B.
A.C.	6 37	30 27	306·7	8·59	1	5·2 7·4	8·025	L.
			306·1	8·61	1	...	8·969	B.
Sirius ...	6 41	106 34	179·2	4·68	1	1 10	8·214	L.
OΣ 156 ..	6 41	71 41	302·1	0·53	1	7·0 7·0	8·164	W.B.
Σ 963 ...	6 43	30 26	79·4	0·54	1	5·9 7·1	8·025	L.
			72·5	0·39	1	..	8·969	B.
β 899 ...	6 53	71 8	265·1	0·81	1	8·7 9·3	6·110	L.
Σ 1037 A.B.	7 7	62 35	306·6	0·84	1	7·0 7·1	8·104	B.
			303·9	0·66	2	...	8·208	W.B.
			303·8	0·68	1	...	8·255	L.
A.C.	...	...	109·5	15·48	1	7·0 11·0	8·255	L.
OΣ 170 ...	7 11	80 31	108·4	1·46	1	7·0 7·5	8·104	B.
			110·3	1·36	1	...	8·164	W.B.
Σ 1074 A.B.	7 15	89 25	133·8	0·68	1	7·8 8·2	6·255	L.
β 577 A.C.	7 15	89 25	103·5	13·77	1	7·8 13·2	6·255	L.
β 21 ...	7 23	82 49	28·2	4·04	2	5·7 11·2	8·249	L.
OΣ 173 A.C.	7 28	56 38	231·3	16·72	1	..	8·244	L.
Σ 1110 (Castor)	7 28	57 53	227·4	5·90	2	2·7 3·7	6·075	L.
			228·1	5·97	3	...	7·142	L.
			225·7	5·74	2	...	7·142	W.B.
			226·0	5·62	3	...	8·180	W.B.
			227·6	5·78	1	..	8·244	L.
OΣ 175 ...	7 29	58 49	324·2	1·02	1	6·0 6·6	6·074	L.
			331·7	0·78	2	...	8·199	W.B.
			331·5	0·72	2	..	8·254	L.
Procyon ..	7 34	84 28	326·0	4·26	3	1 10	8·238	L.
Σ 1126 ..	7 34	84 28	142·2	1·01	2	7·0 7·0	8·233	L.
			141·8	1·24	1	..	8·255	P.M.
OΣ 177 ..	7 35	52 19	122·9	0·53	1	7 7	7·309	L.
			129·7	0·58	1	.	8·238	L.
			124·5	0·45	1	...	8·263	W.B.
OΣ 182 .	7 47	86 21	211·6	0·94	1	7·0 7·5	6·266	L.
Σ 1157 ...	7 49	92 31	246·3	1·07	1	8·0 8·0	6·112	D.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1890+	Obs.
	h m	° ′	°	″				
OΣ 185 ...	7 52	88 35	196·7	0·47	1	6·8 7·1	6·268	L.
β 581 A.B.	7 59	77 25	272·8	0·59	3	8·5 8·6	6·183	L.
			271·0	0·35	1	...	8·164	W.B.
			271·4	0·49	1	...	8·255	L.
A.C.	7 59	77 25	197·0	5·13	3	8·5 11·5	6·183	L.
			201·7	4·89	1	...	8·255	L.
β 582 B.C.	7 59	77 38	58·0	4·39	1	8·7 11·5	6·142	L.
Σ 1179 A.B.	7 59	77 38	204·8	20·43	1	8·5 8·7	6·142	L.
Σ 1187 ...	8 3	57 28	222·0	2·17	1	7·1 8·0	6·142	L.
			225·8	2·04	1	...	7·131	L.
			226·9	1·90	1	...	7·131	W.B.
			224·3	2·18	2	...	8·197	W.B.
Σ 1196 A.B.	8 7	72 3	18·1	1·03	6	5·0 5·7	6·181	L.
(ζ Cancri)			12·9	1·07	1	...	7·131	W.B.
			8·2	1·43	1	...	7·131	L.
			11·1	1·05	5	...	8·187	W.B.
			14·6	1·12	1	...	8·255	L.
A.C.	8 7	72 3	116·3	5·22	6	5·0 5·5	6·181	L.
			115·5	5·20	1	...	7·131	W.B.
			115·0	5·28	1	...	7·131	L.
			115·3	5·25	5	...	8·187	W.B.
			118·8	5·56	1	...	8·255	L.
B.C.	8 7	72 3	128·9	5·50	1	5·7 5·5	6·181	L.
			125·7	5·67	1	...	7·131	W.B.
			123·5	5·47	1	...	7·131	L.
			130·1	5·65	2	...	8·214	W.B.
			128·6	5·79	1	...	8·255	L.
Σ 1202 ..	8 8	78 50	319·1	2·43	2	7·3 9·5	6·285	L.
			317·3	1·87	1	...	8·153	W.B.
β 1244 ...	8 8	87 41	40·1	0·65	1	7·9 8·1	6·268	L.
Σ 1205 ...	8 11	33 14	177·7	...	1	8·8 9·3	7·307	W.B.
Σ 1211 ...	8 11	50 41	307·1	0·81	1	9·1 9·6	6·301	L.
			307·0	0·77	1	...	7·309	L.
Σ 1216 ...	8 16	91 16	184·5	0·87	1	7·5 8·2	6·230	D.
Σ 1273 A.B.	8 41	83 12	212·0	0·22	3	3·5 6·0	6·215	L.
ε Hydræ ...	...	...	204·1	...	1	...	6·244	D.
A.C.	8 41	83 12	230·3	3·56	3	3·5 7·4	6·215	L.
			229·3	3·22	2	...	6·235	D.
			231·8	3·83	1	...	7·364	B.

Star's Name.		R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.		Epoch 1890+	Obs.
		h m	° ′	°	″					
Perrotin	..	8 46	81 18	348·7	0·65	2	7·9	8·6	6·189	L.
Σ 3121	...	9 12	61 0	194·5	0·69	2	7·5	7·8	6·155	L.
				195·2	0·70	1	...		6·244	D.
				196·1	0·70	1	...		7·309	L.
				194·4	0·46	3	...		8·248	W.B.
				189·4	0·63	1	...		8·255	L.
OΣ 201	...	9 18	61 40	221·6	1·34	2	7·5	8·9	6·222	L.
				226·7	...	1	...		7·306	W.B.
				222·4	1·25	1	...		7·315	L.
Σ 1348	...	9 19	83 13	322·0	1·77	2	7·5	7·6	6·222	L.
Σ 1356 (ω Leonis)		9 23	80 30	107·9	0·56	2	6·2	7·0	6·222	L.
				105·8	0·94	1	...		6·244	D.
				107·5	0·84	1	...		7·156	L.
				113·6	0·65	1	...		8·293	B.
				113·7	0·63	1	...		8·345	L.
β 1071 (θ Urs. Maj.)		9 28	37 54	87·1	5·00	1	3	14	8·342	L.
OΣ 208 (φ Urs. Maj.)		9 45	35 28	275·7	0·53	1	5·0	5·6	8·359	L.
Σ 1389	..	9 47	62 33	310·4	...	1	8·0	9·0	7·306	W.B.
				309·7	1·72	1	..		8·153	W.B.
OΣ 215	..	10 11	71 46	209·3	0·82	3	6·7	7·0	6·235	L.
				208·9	1·01	1	...		6·244	D.
				207·2	0·77	2	...		7·325	L.
				207·5	0·65	4	...		8·202	W.B.
Σ 1421	...	10 12	62 0	151·4	4·81	1	7·5	8·5	6·170	L.
Σ 1424 (γ Leonis)		10 14	69 39	115·6	3·63	1	2·0	3·5	6·309	L.
				114·4	3·72	2	..		8·192	W.B.
Σ 1426	A.B	10 15	83 4	281·3	0·65	1	7·8	8·3	6·307	L.
				281·3	0·63	2			8·274	W.B.
	A.C	..	..	5·9	7·75	1	7·8	9·3	6·307	L.
				6·9	7·98	2	...		8·274	W.B.
OΣ 216	...	10 17	74 8	127·7	0·96	1	7	11	6·301	L.
				125·4	1·02	1	..		7·340	L.
Σ 1429	...	10 19	64 50	246·4	...	1	8·1	8·5	7·306	W.B.
				251·1	0·83	3	...		8·186	W.B.
OΣ 217	..	10 21	72 15	145·6	0·76	4	7·3	7·8	6·253	L.
				151·1	0·71	5	...		8·215	W.B.
OΣ 218	..	10 22	85 56	74·0	1·04	1	7	9	6·307	L.
Σ 1457	...	10 33	83 44	316·9	1·16	1	7·4	8·2	8·307	W.B.

Star's Name.	R.A. 1900	N.P.D. 1900.	Position Angle.	Distance	No. of Nights	Mags.	Epoch 1890+	Obs.
	h m	° ′	°	″				
OΣ 224 ...	10 34	80 38	313·3	0·40	2	7·4 8·5	6·285	L.
			317·4	0·58	1	...	7·340	L.
OΣ 225 A.C.	10 35	70 15	350·5	6·54	1	8·2 10·0	6·301	L.
(Perrotin) A.B.	...	...	246·8	0·75	1	8·2 11·2	6·301	L.
OΣ 227 ...	10 35	78 34	343·7	0·48	1	8 9	7·340	L.
			346·3	0·55	1	...	8·296	W.B.
OΣ 228 ...	10 42	66 47	176·2	0·49	1	7 [illegible]	7·340	L.
			186·7	0·58	3	...	8·267	W.B.
			189·7	0·53	1	...	8·301	L.
β 915 ...	10 43	65 5	226·2	...	1	9 9	7·306	W.B.
OΣ 229 ...	10 44	48 21	321·3	1·02	2	6 7	7·230	W.B.
			317·7	0·94	2	...	7·234	L.
			324·2	0·93	1	...	8·142	B.
			321·7	0·89	2	...	8·287	L.
Σ 1504 ...	10 59	85 47	289·1	1·14	2	7·4 7·5	8·340	W.B.
Σ 1523 (ξ Urs. Maj.)	11 13	57 54	170·6	2·00	1	4·0 4·9	6·309	L.
			163·8	1·94	1	...	7·315	L.
			159·4	2·17	1	...	8·222	L.
			157·4	2·16	1	...	8·455	B.
Σ 1527 ...	11 13	75 9	17·7	3·54	1	7·1 8·0	8·364	B.
Σ 1534 ...	11 16	71 14	329·8	5·72	1	8·0 11·0	8·307	W.B.
Σ 1536 (ι Leonis)	11 19	78 54	59·6	2·53	1	3·9 7·1	6·337	L.
			55·3	2·20	1	...	8·263	W.B.
			54·7	2·65	1	...	8·364	B.
OΣ 234 ...	11 26	58 11	7·2	0·13	1	7·0 7·4	7·315	L.
Σ 1555 A.B.	11 31	61 40	345·4	0·42	2	6·4 6·8	6·326	L.
			353·2	0·36	2	...	7·361	L.
			352·2	0·53	2	...	8·262	L.
			350·6	0·51	2	...	8·307	W.B.
A.C.	11 31	61 40	147·0	21·43	2	6·4 10·3	7·361	L.
			145·1	20·57	2	...	8·262	L.
			146·9	20·76	2	...	8·307	L.
OΣ 237 ...	11 33	48 16	263·8	1·08	2	8 9	8·354	L.
β 603 ...	11 45	75 5	320·6	0·87	1	6·4 10·3	6·340	L.
			319·7	0·78	1	...	7·359	L.
			323·2	0·98	1	...	8·301	L.
			321·1	0·88	1	...	8·318	W.B.
Σ 1606 ...	12 5	49 31	334·0	0·91	3	6·2 7·0	8·337	L.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1890+	Obs.
Σ 1621 ...	12 11	83 45	133·8	2·47	1	8·8 10·3	8·307	W.B.
			134·5	2·47	1	...	8·364	B.
Σ 1639 (68 Comæ)	12 19	63 52	199·3	0·15	1	6·5 8·0	6·340	L.
			round	...	1	...	6·367	L.
			196·8	0·24	2	...	7·361	L.
			193·6	0·20	1	...	8·307	L.
Σ 1643 ...	12 22	62 23	41·0	2·06	2	8·3 8·6	7·356	W.B.
			37·9	1·91	1	...	8·296	W.B.
			42·6	2·00	1	...	8·307	L.
Σ 1647 ...	12 25	79 44	222·6	1·37	2	7·5 8·0	7·300	W.B.
			224·6	1·00	1	...	7·342	L.
			224·4	0·89	1	...	8·296	W.B.
			218·1	0·97	2	...	8·410	B.
Σ 1658 ...	12 30	81 58	358·4	2·46	1	8·0 9·8	6·334	L.
			360·2	2·38	1	...	7·392	L.
			361·0	2·54	1	...	8·301	L.
			356·8	2·67	1	...	8·307	W.B.
			358·0	2·54	3	...	8·377	B.
Σ 1661 ...	12 31	78 1	241·9	2·32	1	8·5 8·5	7·392	L.
			237·1	2·51	1	...	8·296	W.B.
			235·4	2·84	1	...	8·364	B.
Σ 1663 ...	12 32	68 13	101·8	0·71	2	7·8 8·7	6·345	L.
			107·5	0·60	2	...	7·387	L.
			109·0	0·89	1	...	8·293	B.
			102·8	0·65	1	...	8·301	L.
			100·6	0·64	1	...	8·318	W.B.
Σ 1670 (γ Virg.)	12 36	90 52	153·2	5·96	1	3·0 3·0	6·367	L.
			150·0	5·99	1	...	7·319	W.B.
			150·7	5·59	1	...	8·307	W.B.
			149·0	5·99	2	...	8·355	B.
Σ 1687 A.B.	12 48	68 11	74·7	1·10	4	5·1 7·8	6·342	L.
			71·6	1·06	1	...	7·340	L.
			76·5	1·24	1	...	8·296	W.B.
			76·8	1·30	1	...	8·301	L.
			77·4	1·37	2	...	8·374	B.
A.C.	12 48	68 11	126·7	28·80	1	5·1 9·0	7·340	L.
			125·2	28·85	1	...	8·301	L.
			124·2	...	1	...	8·455	B.
OΣ 256 ...	12 51	90 25	263·4	0·80	1	7·0 7·5	6·381	D.

Star's Name.	R.A. 1900 h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1890+	Obs.
OΣ 256 ...	12 51	90 25	258·3	0·75	1	7·0 7·5	6·367	L.
β 112 ...	12 55	70 59	292·0	2·24	1	9·1 9·8	6·416	L.
			293·1	2·40	1	...	8·293	B.
			294·3	1·68	1	...	8·375	L.
β 1082 ...	12 57	33 5	85·4	1·26	3	6·0 9·6	8·295	L.
Σ 1711 ...	12 57	75 59	349·6	0·98	1	8·5 9·0	6·416	L.
			349·5	0·82	1	...	7·343	L.
			349·3	0·89	3	...	8·332	W.B.
			353·9	1·01	1	...	8·364	B.
			347·7	0·89	1	...	8·375	L.
β 929 ...	12 58	93 7	212·3	0·60	1	6·0 6·3	8·318	W.B.
β 930 ...	13 1	44 12	116·7	2·75	1	6·2 11·3	8·430	L.
			119·0	3·07	1	...	8·460	B.
β 1083 A.B.	13 2	60 26	221·1	6·08	1	6·5 11·5	7·381	L.
			218·1	6·49	2	...	8·366	L.
A.C.	13 2	60 26	243·6	0·42	1	11·5 11·7	7·381	L.
			234·7	0·40	1	...	8·301	L.
OΣ 260 ...	13 3	62 31	123·7	0·53	2	8 8	7·361	L.
			126·1	0·58	2	...	8·307	W.B.
			120·2	0·54	2	...	8·357	L.
Σ 1728 (42 Comæ)	13 5	71 57	201·1	0·15	1	5·5 5·9	6·334	L.
			204·7	...	1	...	6·381	D.
			350·1	0·07	1	...	7·340	L.
			round	...	1	...	7·364	L.
			204·0	0·17	3	...	8·395	L.
OΣ 261 ...	13 7	57 22	346·3	1·31	1	7·0 7·5	7·392	L.
			345·6	1·40	1	...	8·490	L.
			345·0	1·24	2	...	8·507	W.B.
β 800 ...	13 11	72 20	115·0	2·60	2	7·5 10·2	6·405	L.
			112·1	2·44	1	...	7·392	L.
			113·5	2·33	1	...	8·370	W.B.
			117·0	2·53	3	...	8·395	L.
Σ 1733 ...	13 11	72 10	125·2	5·21	2	8·2 9·8	6·392	L.
			127·2	4·91	1	...	7·392	L.
			127·0	4·82	2	...	8·375	L.
Σ 1734 ...	13 15	86 30	189·7	0·85	1	7 8	8·307	W.B.
			187·0	1·24	1	...	8·313	B.
Σ 1742 ...	13 19	88 0	351·4	1·09	1	7·4 7·9	8·307	W.B.
OΣ 266 ...	13 23	73 41	339·1	1·70	2	7·3 7·8	6·411	L.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.		Epoch 1890+	Obs.
	h m	° ′	°	″					
OΣ 266 ...	13 23	73 41	341·7	1·57	1	7·3	7·8	7·392	L.
			338·2	1·51	3	...		8·328	W.B.
			340·4	1·65	2	...		8·397	L.
OΣ 269 ...	13 28	54 34	202·7	0·38	1	6·5	7·0	6·312	L.
			214·0	0·10	2	...		7·357	L.
			214·5	0·30	2	...		8·462	L.
Σ 1768 ..	13 33	53 10	136·3	1·17	1	5·0	7·6	6·312	L.
			133·3	1·03	1	...		7·392	L.
			140·0	0·92	2	...		8·460	L.
			139·6	0·68	1	...		8·504	W.B.
			133·3	0·97	2	...		8·559	B.
β 612 ...	13 34	78 45	212·1	0·34	2	6·0	6·5	6·410	L.
			223·9	0·33	2	...		7·366	L.
			210·9	0·48	1	...		8·318	W.B.
			221·0	0·39	2	...		8·397	L.
Σ 1777 ...	13 38	85 55	228·0	3·76	1	5·8	8·2	6·381	D.
Σ 1781 ..	13 41	82 23	272·3	1·07	1	7·5	8·0	6·381	D.
			278·8	1·27	1	...		7·371	W.B.
			278·9	0·95	1	...		7·413	L.
Σ 1785 .	13 44	62 30	263·2	1·44	1	7·2	7·5	6·383	L.
			264·0	1·31	2	...		7·352	W.B.
			268·4	1·41	1			8·318	W.B.
β 613	13 48	54 50	153·6	0·48	1	9·1	9·1	8·430	L.
β 1270 .	13 59	80 52	356·2	0·43	1	8·2	8·3	6·405	L.
			346·0	0·27	1	...		7·413	L.
			341·8	0·43	2	.		8·438	L.
			344·9	0·45	1	...		8·438	W.B.
β 30 ..	13 53	70 2	201·3	8·75	1	8·0	11·0	8·457	L.
Σ 1808	14 5	62 54	78·1	3·40	1	8·0	9·0	6·457	W.B.
			69·5	3·39	1	...		7·353	B.
			74·7	2·91	1	...		7·378	W.B.
OΣ 278 ..	14 8	45 21	97·5	0·27	1	7·5	7·5	8·430	L.
Σ 1819 ...	14 10	86 22	5·0	1·50	1	7·9	8·0	6·465	D.
			2·9	1·30	1	...		7·318	W.B.
			0·0	1·23	1	..		8·427	W.B.
			1·4	1·26	1	...		8·457	L.
β 1272 A.B.	14 14	40 47	132·8	1·32	2	8·4	9·5	7·520	L.
			129·3	1·18	1	...		8·528	L.
			134·2	1·44	1	...		8·630	B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Magn.		Epoch 1890+	Obs.
	h m	° ′	°	″					
β 1272 A.C.	14 14	40 47	319·0	...	2	8·4	8·5	7·520	L.
			321·4	23·60	1	...		8·630	H.
β 1273 ...	14 15	41 35	193·3	0·94	2	8·6	9·8	7·520	L.
			199·4	0·80	1	...		8·528	L.
			193·6	...	1	...		8·630	H.
Σ 1834 ...	14 17	40 56	166·5	...	1	7·5	7·5	7·512	L.
			round	...	1	...		7·630	B.
Σ 1835 A.B.	14 18	81 6	189·9	6·59	3	5·0	8·2	8·417	L.
B.C.	...	...	336·6	0·30	2	8·2	6·8	8·438	L.
Σ 1837 ...	14 19	101 12	305·4	0·68	1	7·0	8·0	6·381	D.
Σ 1865 (ζ Bootis)	14 36	75 49	93·2	0·21	1	3·5	3·9	6·383	L.
			round	...	2	...		7·367	L.
			78	...		...		7·413	L.
			72·4	0·1	2	...		8·443	L.
Σ 1867 ...	14 36	58 15	15·3	1·24	1	7·7	8·2	6·457	W.B.
			16·1	1·03	1	...		7·320	L.
			13·0	1·28	2	...		7·326	W.B.
			13·1	0·82	2	...		8·471	W.B.
			14·7	1·28	2	...		8·471	B.
			17·1	1·19	1	...		8·528	L.
Σ 1866 ...	14 37	80 2	208·3	1·11	1	8·0	8·0	8·608	B.
Σ 1870 ...	14 37	81 29	230·1	4·64	1	7·5	10	8·608	B.
Σ 1877 (ε Bootis)	14 38	62 29	327·4	3·12	1	3·0	6·3	6·457	W.B.
			323·7	3·01	1	...		7·378	W.B.
			329·1	2·81	1	...		8·438	W.B.
			334·8	2·87	1	...		8·455	B.
Σ 1879 ...	14 41	79 55	144·8	0·49	3	8·0	8·5	6·382	L.
			136·3	0·60	2	...		7·354	W.B.
			140·4	0·38	3	...		7·370	L.
			136·4	0·53	1	...		8·427	W.B.
			139·5	0·46	4	...		8·437	L.
OΣ 285 ...	14 42	47 11	326·9	0·41	2	7·1	7·6	7·322	L.
Σ 1883 ...	14 44	83 38	254·7	0·56	1	7·0	7·0	6·383	L.
			245·9	0·55	1	...		8·452	L.
			245·6	0·52	2	...		8·482	W.B.
			242·9	0·72	1	...		8·487	B.
Σ 1888 (ξ Bootis)	14 47	70 27	220·6	2·83	1	5·1	7·4	6·383	L.
			218·7	2·55	1	...		6·463	C.
			218·8	2·83	1	...		6·463	W.B.

Star's Name.		R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights	Mags.		Epoch 1890+	Obs.
Σ 1888 (ξ Bootis)		14 47	70 27	219·2	2·82	1	5·1	7·4	7·334	W.B.
				212·2	2·87	1	...		8·293	B.
				216·1	2·99	1	...		8·451	L.
β 942	...	14 47	89 58	200·1	0·94	1	9·1	9·2	7·446	L.
OΣ 287	...	14 47	44 38	319·2	0·69	2	8	9	7·322	L.
				317·7	0·85	1	...		7·329	W.B.
				319·0	0·81	2	...		8·559	B.
β 31	A.B.	14 48	70 50	194·5	1·53	2	8·4	9·7	6·375	L.
				193·7	1·52	1	...		7·438	W.B.
				194·4	1·36	1	...		7·446	L.
				196·2	1·45	1	...		8·452	L.
	A.C.	14 48	70 50	167·3	9·76	2	8·4	12·2	6·375	L.
				166·0	9·05	1	...		8·457	L.
OΣ 288	...	14 49	73 51	188·9	1·67	2	6·5	7·0	6·367	L.
				189·4	1·33	1	...		7·444	W.B.
				191·2	1·40	1	...		8·451	L.
				191·8	1·28	1	...		8·531	B.
Σ 1908	...	15 1	55 7	140·7	1·30	3	8	9	7·471	W.B.
				146·7	1·10	1	...		8·504	W.B.
				146·8	1·38	1	...		8·528	L.
Σ 1926	..	15 12	51 20	251·8	0·91	1	6·5	8·2	8·528	L.
Σ 1932	..	15 14	62 48	141·8	0·78	2	5·5	6·0	6·367	L.
				145·5	0·77	3	...		7·347	W.B.
				145·4	0·79	2	...		7·369	L.
				145·1	0·65	1	...		8·531	W.B.
Σ 1937 (η Cor. Bor.)		15 19	59 21	130·8	0·44	3	5·0	5·7	6·347	L.
				149·1	0·40	4	...		7·359	L.
				166·1	0·42	1	...		8·468	W.B.
				161·2	0·37	2	...		8·492	L.
Σ 1938	..	15 20	52 16	79·4	0·86	3	4	6	7·334	L.
OΣ 296	...	15 22	45 38	313·4	1·63	1	8	9	7·329	W.B.
				302·2	1·35	1	...		8·531	W.B.
				308·7	1·54	1	...		8·534	L.
				300·1	1·50	1	...		8·706	B.
Σ 1957	..	15 31	76 42	156·3	1·17	1	8·0	9·5	6·356	L.
				158·4	1·35	1	...		6·465	C.
				157·1	1·07	1	...		7·323	L.
				151·1	1·28	3	...		7·374	W.B.
				153·1	1·30	1	...		8·427	W.B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Magn.		Epoch 1890+	Obs.
	h m	° ′	°	″					
OΣ 298 ...	15 32	49 50	176·0	0·85	2	7	8	7·418	L.
			173·7	1·01	2	...		7·433	W.B.
			178·9	1·03	1	...		8·531	W.B.
			178·0	0·90	1	...		8·534	L.
Σ 1967 (γ Cor. Bor.)	15 38	63 18	118·5	0·60	1	4·0	7·0	6·454	L.
			120·1	0·44	4	...		7·429	L.
			118·8	0·84	1	...		8·487	B.
			114·4	0·43	2	...		8·496	L.
			117·1	0·55	1	...		8·531	W.B.
β 621 ...	15 47	44 55	57·0	0·54	1	8·1	9·3	8·534	L.
OΣ 303 ...	15 56	76 28	138·4	0·89	1	7·0	8·0	6·353	L.
			141·2	0·88	2	...		7·381	W.B.
			141·6	0·67	2	...		7·436	L.
			140·4	0·80	3	...		8·474	W.B.
			146·7	1·03	1	...		8·487	B.
Σ 2015 A.C.	16 5	44 22	160·2	2·67	1	7·8	8·8	7·342	L.
			160·5	3·00	1	...		8·531	W.B.
			162·0	2·71	1	...		8·534	L.
β 355 A.B.	16 5	44 22	278·5	0·44	1	7·8	8·9	7·342	L.
			278·1	0·42	2	...		8·534	W.B.
A.D.	16 5	44 22	99·2	12·87	1	7·8	13	8·531	W.B.
			98·0	12·49	1	...		8·534	L.
Σ 2021 ...	16 8	76 12	332·6	3·99	2	7·0	7·1	8·630	B.
Σ 2026 ...	16 12	82 21	266·5	0·78	1	8·5	9·5	7·372	W.B.
			260·0	0·79	1	...		8·528	W.B.
Σ 2032 ...	16 11	55 53	212·1	4·14	1	5·0	6·1	6·449	L.
			209·0	4·17	1	...		6·454	W.B.
			211·6	4·42	1	...		7·372	L.
			213·9	4·58	1	...		8·641	B.
β 951 ..	16 20	56 26	56·8	1·07	1	8·1	9·0	8·531	L.
β 814 ...	16 24	49 53	325·2	0·28	1	8·4	8·4	8·534	L.
Σ 2052 ...	16 24	71 21	95·8	2·32	1	7·5	7·5	6·463	C.
			95·2	1·81	3	...		7·428	W.B.
			94·8	1·50	1	...		8·439	W.B.
			94·1	1·83	1	...		8·599	L.
			94·0	1·93	1	...		8·619	B.
Σ 2055 (λ Oph.)	16 25	87 47	47·0	1·40	2	4·0	6·1	6·486	L.
			50·6	1·59	1	...		8·487	B.
Σ 3105 ...	16 26	96 46	24·8	0·75	1	7·5	7·5	8·487	B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1890+	Obs.
	h m	° ′	°	″				
Σ 2084 (ζ Herc.)	16 36	58 12	6·0	0·54	2	3·0 6·5	6·452	L.
			2·3	0·46	3	...	7·404	L.
			288·0	0·63	3	...	8·588	L.
			288·8	0·56	2	...	8·665	W.B.
			285·3	0·40	1	...	8·739	B.
Σ 2091 ...	16 39	48 37	302·1	0·82	1	7·5 8·0	7·323	L.
			309·8	0·81	1	...	7·334	W.B.
			303·5	0·99	1	...	8·613	W.B.
			304·8	1·07	1	..	8·663	B.
			303·1	0·89	1	...	8·704	L.
Da. 15 ...	16 40	46 30	329·5	0·30	1	8·0 8·5	7·323	L.
			328·3	0·52	1	...	8·613	W.B.
			327·8	0·50	1	...	8·704	L.
Σ 2106 ...	16 47	80 26	300·6	0·44	1	6·7 8·4	6·460	L.
OΣ 315 ...	16 46	88 37	165·1	0·65	1	6 [illegible]	7·444	W.B.
			163·1	0·67	1	...	7·501	L.
Σ 2107 ...	16 48	61 10	293·9	0·44	1	6·7 8·5	7·603	L.
Σ 3107 ...	16 53	85 53	96·2	1·33	1	8·5 8·5	6·520	L.
Σ 2114 ...	16 56	81 24	157·6	1·14	2	6·5 8·0	6·538	L.
			162·6	0·99	1	...	7·444	W.B.
			158·9	1·10	1	..	8·427	W.B.
Σ 2118 ...	16 56	24 50	22·2	0·18	1	5·5 6·5	7·342	L.
Σ 2120 ...	17 0	61 45	242·8	6·16	1	6·8 9·0	8·857	L.
β 357 ..	17 1	79 19	300·0	0·99	2	8·4 9·4	6·529	L.
Σ 2140 (α Herc.)	17 10	75 30	115·9	4·87	1	3·0 6·1	6·526	L.
			115·7	4·94	2		7·535	L.
			116·9	5·11	1		7·539	P.M.
OΣ 327 ...	17 12	33 45	321·1	0·34	1	7·6 8·0	7·381	L.
β 1200 ...	17 12	75 1	194·1	1·21	2	7·8 12·2	6·466	L.
*	17 15	57 28	297·4	2·68	1	10·0 11·0	6·465	L.
β 629 .	17 15	57 50	344·1	0·97	2	8·4 8·7	8·645	W.B.
			341·1	·20	2	.	8·705	B.
β 630 ...	17 17	57 36	225·0		2	8·5 9·6	8·656	W.B.
			221·9	1·55	2		8·701	B.
β 46 ...	17 18	75 2	182·2	1·20	1	8·0 14·0	6·531	L.
Σ 2163 ...	17 20	47 45	93·2	1·42	1	10 10	8·608	B.
			93·2	1·62	2		8·650	W.B.
β 1250 ...	17 21	59 7	66·8	2·56	1	9·4 9·5	6·463	L.
			71·1	1·90	1	...	7·528	L.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1890+	Obs.
β 1250 ...	17 21	59 7	69·2	1·88	1	9·4 9·5	7·537	W.B.
			65·9	1·80	1	...	8·624	W.B.
			64·2	2·27	2	..	8·702	B.
			65·7	2·18	1	...	8·704	L.
Σ 2173 ...	17 25	90 59	337·3	1·29	1	6·0 6·3	6·580	D.
			336·4	0·97	1	...	6·580	L.
			334·7	...	1	...	6·580	N.
			333·7	0·90	1	...	7·444	W.B.
			341·1	1·22	2	...	8·743	B.
OΣ 331 ...	17 27	87 7	338·5	0·85	1	8·0 9·0	6·580	L.
			338·3	...	1	...	6·580	N.
			338·0	1·09	1	...	7·444	W.B.
*	17 26	87 4	11·3	0·78	1	10·0 12·0	6·580	L.
			16·2	...	1	...	6·580	N.
β 1121 ...	17 32	77 24	247·4	0·72	1	8·5 9·0	6·474	L.
			248·5	0·60	1	...	7·528	L.
			244·2	0·73	1	...	7·562	W.B.
β 631 ...	17 34	90 35	33·3	0·97	1	7·5 7·6	6·690	D.
β 1251 ...	17 38	73 59	84·9	1·25	3	6·0 11·5	6·508	L.
Σ 2203 ...	17 38	48 18	325·6	0·76	1	7·5 7·8	6·465	L.
			322·2	0·66	2	...	8·618	W.B.
			323·3	0·80	1	...	8·619	B.
Σ 2199 ...	17 37	34 12	88·6	1·73	2	7 8	8·630	B.
Σ 2205 ...	17 41	72 15	306·0	1·82	1	8·3 8·6	6·531	L.
			308·5	...	1	...	6·561	W.B.
			307·0	2·07	1	.	7·534	L.
			308·8	...	1	...	8·641	B.
Σ 2215 ...	17 42	72 16	293·3	0·79	2	5·9 8·0	6·504	L.
			296·9	0·61	2	...	7·534	L.
A.C. 7 (μ′ Herc.)	17 43	62 13	46·9	1·41	2	10·0 10·5	6·539	L.
OΣ 337 ...	17 45	82 44	102·8	0·45	2	7·5 7·5	6·601	L.
OΣ 338 ...	17 47	74 39	14·4	0·72	3	6·5 7·0	6·509	L.
			15·5	1·02	1	...	6·520	C.
*	17 47	74 39	352·6	0·84	1	...	6·476	L.
A.C. 9 ...	17 50	60 10	53·4	1·03	2	8·4 8·7	6·457	L.
β 1127 .	17 59	45 47	147·0	0·57	1	7·8 9·7	7·756	L.
			139·6	0·74	1	...	8·613	W.B.
			135·6	0·76	1	...	8·704	L.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1890+	Obs.
	h m	° '	°	"				
Σ 2272 (70 Oph.)	18 0	87 27	288·1	2·33	6	4·3 6·3	6·590	W.B.
			289·5	2·23	1	...	6·608	D.
			290·9	2·18	1	...	6·619	N.
			290·1	2·03	5	...	6·649	L.
			282·5	2·01	9	...	7·520	W.B.
			282·5	1·89	1	...	7·578	L.
			273·4	1·82	8	...	8·526	W.B.
			273·7	1·75	1	.	8·619	B.
			269·6	1·62	1	..	8·704	L.
Σ 2275 ...	18 0	50 38	271·5	0·20	1	9·0 9·2	7·474	L.
			274·5	0·24	1	...	8·613	W.B.
			273·0	0·25	1	..	8·701	L.
			264·3	0·20	1	..	8·706	[illegible]
*	18 1	50 36	131·7	0·80	2	...	8·657	[illegible]
			136·2	0·79	2	...	8·665	W.B.
			136·6	0·62	2	...	8·703	L.
A.C. 15 (99 Herc.)	18 3	59 27	305·0	0·85	2	6·0 11·0	6·616	L.
			312·0	0·99	1	...	8·418	L.
			308·8	0·99	1	...	8·663	B.
Σ 2289 ...	18 6	73 33	228·8	1·24	2	6·5 7·0	6·550	L.
			229·4	1·79	2	...	6·567	W.B.
			227·0	0·99	1	. .	7·534	L.
			222·0	1·35	1	...	8·548	C.
Σ 2281 ...	18 4	86 2	229·2	0·43	2	5·7 7·2	6·594	L.
Σ 2285 ...	18 5	76 28	228·3	1·11	1	8·2 10·0	6·520	D.
			227·5	1·25	1	. .	6·580	L.
β 1091 ...	18 9	51 26	25·4	0·66	1	8·6 8·6	6·693	L.
β 641 ...	18 17	68 33	336·5	1·31	1	7·3 9·0	6·611	D.
			346·5	0·92	4	...	6·625	L.
			349·4	1·04	2	...	7·531	L.
β 1203 ...	18 21	39 15	72·6	0·43	1	7·5 7·7	6·739	L.
Σ 2315 ...	18 21	62 39	218·3	0·29	2	7·5 9·0	6·596	L.
			210·5	0·32	2	..	7·579	L.
*	18 20	62 40	315·6	4·26	1	9·5 10·5	6·742	L.
			321·1	4·87	2	...	7·579	L.
OΣ 543 ...	18 23	43 11	127·4	1·08	1	8·0 10·0	6·742	L.
			135·3	1·04	2	...	8·619	W.B.
			138·4	1·13	2	...	8·641	B.
OΣ 351 .	18 23	41 19	24·6	0·49	1	7·0 7·0	6·742	L.

Star's Name.		R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights	Mags.		Epoch 1890+	Obs.
		h m	° ′	°	″					
OΣ 351	...	18 23	41 19	16·6	0·55	2	7·0	7·0	8·619	W.B.
				22·9	0·57	2	...		8·641	B.
OΣ 354	...	18 26	83 20	167·0	0·78	2	7	8	7·564	W.B.
OΣ 357	...	18 31	78 34	262·3	0·34	2	...		8·646	W.B.
OΣ 358	...	18 31	73 12	195·4	1·97	2	7·0	7·5	6·551	L.
				189·9	2·05	2	...		6·597	W.B.
				195·5	1·98	1	...		6·687	D.
				191·4	1·60	4	...		7·526	W.B.
				197·1	1·87	1	...		7·534	L.
Σ 2356	...	18 34	61 23	61·3	0·81	2	8·2	8·6	6·452	L.
				53·7	0·90	1	...		7·737	L.
				54·2	1·18	1	...		8·663	B.
* ...	...	18 34	61 18	254·8	1·31	2	9·0	10·0	6·452	L.
				250·8	1·09	1	...		7·737	L.
				250·4	1·58	1	...		8·663	B.
Hough 87	...	18 34	73 34	106·7	0·43	1	7·8	8·1	6·578	L.
Σ 2367	A.B.	18 37	73 12	267·5	0·25	2	7·2	7·6	7·521	L.
	A.C.	...	...	191·3	14·11	1	7·2	8·2	7·455	L.
Σ 2384	...	18 39	23 0	313·6	0·49	1	8·0	8·2	7·413	L.
Σ 2375	...	18 41	84 36	114·0	2·34	2	6·2	6·6	6·611	W.B.
Σ 2400	A.B.	18 44	73 53	184·0	1·89	2	8·0	11·1	6·616	L.
				184·2	1·95	2	...		7·559	L.
	A.C.	...	...	184·6	2·93	2	8·0	11·0	6·616	L.
				185·3	2·93	2	...		7·559	L.
				181·8	2·83	1	...		8·663	B.
	A.D.	...	...	186·7	0·50	2	8·0	9·5	6·616	L.
				140·0	0·49	1	...		7·539	L.
	B.C.	...	...	199·6	0·76	1	11·1	11·0	6·772	L.
				186·7	1·09	1	...		7·539	L.
β 971	...	18 45	40 43	11·6	0·30	1	6·8	9·2	7·430	L.
Σ 2402	...	18 45	79 25	207·6	0·74	1	8·0	8·4	7·575	W.B.
				205·6	0·92	1	...		8·468	W.B.
β 137	A.B.	18 50	52 45	132·3	1·34	3	8·2	8·7	6·597	L.
				136·7	1·55	1	...		6·772	W.B.
				128·2	1·47	1	...		7·438	W.B.
				130·6	1·24	2	...		7·462	L.
				127·9	1·29	1	...		8·468	L.
				127·3	1·29	1	...		8·624	W.B.
	A.C.	...	...	321·0	18·20	1	8·2	11·5	6·460	L.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle °	Distance. ″	No. of Nights.	Mags.	Epoch 1890+	Obs.
β 137 A.C.	18 50	52 45	320·6	19·15	1	8·2 11·5	7·474	L.
*	18 50	52 37	169·0	6·22	1	...	6·772	L.
β 1255 ...	18 52	41 16	65·6	0·86	1	5·8 12·5	7·619	L.
Σ 3130 ...	18 53	45 55	262·3	2·50	3	6·7 10·4	7·444	L.
*	18 54	45 56	137·3	3·07	1	10 11	7·413	L.
Σ 2422 ...	18 53	64 2	98·5	0·59	1	7·9 8·2	7·586	L.
			91·6	0·77	1	...	8·468	W.B.
β 648 ...	18 53	86 21	225·1	1·33	1	6·0 9·2	6·474	D.
			233·2	1·27	4	...	6·622	L.
			229·2	1·36	1	...	7·438	W.B.
			231·2	1·14	4	...	7·540	L.
			230·2	1·50	1	...	8·539	L.
			228·3	1·24	2	...	8·668	B.
β 649 ...	18 54	57 42	7·9	1·44	2	8·2 10·6	7·751	L.
			2·8	1·76	1	...	8·706	B.
Σ 2438 ...	18 56	31 56	Round	...	1	7·2 7·7	7·417	L.
Σ 2437 ...	18 57	69 57	55·4	0·68	1	7·8 8·2	7·553	W.B.
ζ Aquilæ ...	19 1	76 17	56·8	5·87	4	3·0 15·0	6·639	L.
Σ 2454 ...	19 2	59 43	244·6	0·88	1	8 9	7·438	W.B.
			241·6	0·98	1	...	7·449	L.
			248·1	0·98	1	...	8·706	B.
Σ 2455 ...	19 3	67 59	79·2	3·47	1	7 8	7·501	L.
			83·1	3·59	1	...	7·528	W.B.
			83·2	3·81	1	...	8·775	B.
Σ 2488 ...	19 11	70 9	328·6	1·40	1	8·5 9·7	6·591	L.
			325·7	1·73	1	...	6·657	W.B.
			324·9	1·48	1	...	7·534	L.
			330·4	1·65	2	...	7·554	W.B.
OΣ 368 ...	19 11	74 1	212·1	0·96	1	8 9	6·507	L.
			213·6	0·98	1	...	7·534	L.
			213·2	0·88	2	...	7·554	W.B.
OΣ 371 ...	19 12	62 42	160·0	0·79	2	7 7	6·619	L.
			155·8	0·73	2	...	7·520	L.
			155·6	0·79	2	...	7·543	W.B.
			158·0	0·83	1	...	8·468	L.
β 1256 ..	19 14	83 51	40·1	...	1	8·3 8·3	7·761	B.
			36·1	0·60	1	.	8·739	B.
β 141 A.B.	19 18	67 42	81·6	0·84	1	7·5 8·5	7·567	L.
			78·9	0·86	1	...	7·950	W.B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1890+	Obs.
	h m	° ′	°	″				
β 141 C.D.	19 18	67 42	183·0	5·75	1	10·5 10·5	7·567	L.
			181·7	5·39	1	...	7·950	W.B.
Σ 2525 ...	19 22	62 54	147·2	0·51	4	7·4 7·6	6·595	L.
			323·9	0·39	5	...	7·695	L.
			317·3	0·50	3	...	8·621	L.
			319·8	0·39	1	...	8·739	B.
Σ 2536 ...	19 27	72 25	68·3	1·86	1	8·0 11·0	6·556	L.
			72·6	1·60	1	...	8·520	L.
			76·0	1·63	2	...	8·521	B.
*	19 27	72 9	341·0	11·30	1	10·5 11·0	6·556	L.
Σ 2539 ...	19 28	61 57	362·2	5·57	2	7·9 9·7	6·506	L.
			362·2	5·91	1	...	8·518	B.
			359·6	5·34	1	...	8·523	W.B.
OΣ 375 ...	19 30	72 7	137·5	0·58	2	8·0 9·0	6·561	L.
Σ 2556 ...	19 35	67 58	142·3	0·44	3	7·3 7·8	6·587	L.
			145·9	0·48	1	...	8·739	B.
β 1132 ...	19 39	63 18	227·1	0·47	2	8·3 8·7	7·679	L.
β 658 ...	19 40	63 9	291·1	0·50	3	6·7 9·7	7·630	L.
Σ 2579 (δ Cygni)	19 42	45 7	121·8	1·51	1	3 8	7·539	L.
			131·4	1·15	1	...	8·953	B.
A.G.C. 11 (ζ Sag.) A.B.	19 44	71 7	163·9	0·19	1	4·5 6·0	7·693	L.
			163·9	0·38	2	...	8·773	L.
			170·9	0·47	2	...	8·809	B.
			151·5	0·33	1	...	8·843	W.B.
Σ 2585 A.C.	...	...	311·9	8·79	1	4·5 8·0	7·693	L.
			311·9	8·51	2	...	8·773	L.
			310·4	8·73	1	...	8·780	B.
OΣ 387 ...	19 45	54 57	347·7	0·48	1	7·5 8·0	6·559	L.
			344·5	0·52	2	...	7·782	L.
			342·0	0·40	1	...	8·534	L.
			339·6	0·53	1	...	8·717	W.B.
A.C. 16 ...	19 53	63 2	230·9	0·39	2	7 9	7·685	L.
			238·7	0·49	2	...	8·726	W.B.
β 425 ...	19 53	69 59	242·1	1·28	1	8·4 8·5	6·613	L.
			241·5	1·32	5	...	8·585	W.B.
Σ 2607 A.B. (OΣ 392)	19 54	48 0	299·7	0·45	1	7 9	8·704	L.
A.C.	...	...	109·4	3·21	1	7 9	8·704	L.
β 1133 ...	19 56	58 27	335·4	0·68	2	6·8 9·5	7·645	L.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1890+	Obs.
β 1133 ...	19 56	58 27	337·4	0·73	1	6·8 9·5	8·734	W.B.
β 439 ...	19 56	60 23	241·8	3·28	1	7·9 12·7	7·750	L.
β 1258 ...	19 56	60 23	153·2	1·23	1	8·0 10·7	7·780	L.
			156·3	1·35	1	...	8·734	W.B.
OΣ 395 ...	19 58	65 21	284·2	0·72	1	5·5 6·0	6·690	D.
			276·7	0·62	1	...	6·613	L.
			282·2	0·55	1	...	7·570	W.B.
			277·2	0·81	1	...	8·704	L.
β 1206 ...	20 15	53 35	359·7	1·80	1	7·8 10·8	7·737	L.
Σ 2695 ...	20 27	64 39	82·2	1·20	1	6·2 8·0	6·690	D.
			76·3	1·12	1	...	6·613	L.
			77·7	0·93	1	...	7·528	L.
			78·1	1·08	1	...	7·562	W.B.
			77·7	1·27	1	...	8·548	C.
			76·7	0·78	2	...	8·678	W.B.
β 151 A.B. (β Delph.)	20 33	75 45	4·7	0·66	1	4·5 6·0	8·753	L.
Σ 2704 A.C.	20 33	75 45	117·8	26·17	1	4·5 11·0	8·753	L.
A.B.	...	...	333·3	37·32	1	4·5 11·0	8·753	L.
Hough 137 .	20 36	60 34	285·8	1·10	1	7·0 10·0	6·742	L.
			281·2	0·95	1	...	7·664	W.B.
			283·8	0·98	2	...	8·702	W.B.
Σ 2714 ...	20 36	60 34	339·0	5·06	1	8·5 12·0	8·742	L.
β 64 ...	20 40	77 40	183·8	0·57	1	8·3 8·3	7·576	W.B.
			186·3	0·49	1	...	7·821	D.
			188·6	0·55	1	...	8·753	L.
Σ 2737 A.B. (ε Equul.)	20 54	86 5	284·7	0·85	2	5·7 6·2	8·757	B.
A.C.	...	...	74·1	10·37	1	5·7 7·1	8·739	B.
Σ 2744 ..	20 58	88 51	172·1	1·45	1	6·3 7·0	6·572	W.B.
			166·1	1·80	1	...	7·794	B.
			166·8	1·51	1	...	8·794	B.
β 156 ...	20 58	43 50	247·6	1·11	2	7·5 9·9	6·644	L.
β 69 .	20 58	68 43	311·7	0·72	1	8·3 9·1	6·717	L.
			315·2	1·02	2	...	7·652	W.B.
			311·1	0·97	1	...	8·711	W.B.
			313·9	0·85	1	...	8·726	L.
β 1138 ..	20 59	44 36	189·2	0·36	1	7·2 8·5	7·920	L.
Σ 2749 A.B.	21 0	86 52	155·6	3·10	1	7·7 8·9	8·794	B.
B.C.	...	...	152·7	0·74	1	8·9 10·0	8·794	B.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1890+	Obs.
β 679 ...	21 2	46 43	54·0	0·42	1	10·0 10·0	6·559	L.
Ho. 152 ...	21 8	62 7	320·6	0·68	1	8·5 9·5	7·701	W.B.
			319·1	0·51	1	...	8·711	W.B.
			324·1	0·57	1	...	8·720	L.
A.G.C. 13 (τ Cygni)	21 11	52 23	340·9	0·48	2	3·9 10·0	6·643	L.
			311·2	0·58	1	...	8·819	L.
Σ 2799 (26 Peg.)	21 24	79 21	118·3	1·69	1	7·0 7·0	6·657	W.B.
			117·1	1·40	2	...	7·564	W.B.
			117·1	1·27	2	...	8·693	W.B.
			120·7	1·27	1	...	8·723	L.
			118·0	1·33	1	...	8·775	B.
Σ 2804 ...	21 28	69 44	331·2	3·42	1	7·3 8·0	6·561	D.E.
			331·8	3·16	3	...	6·620	W.B.
			...	2·92	1	...	6·709	D.
			335·0	2·95	1	...	6·709	C.
Σ 2822 (μ Cygni)	21 40	61 42	122·6	2·83	1	4·0 5·0	6·572	L.
			121·6	2·84	1	...	7·526	W.B.
			124·2	[illegible]	1	...	7·761	D.
			125·0	2·93	1	...	8·611	L.
Σ 2824 A.C. (κ Pegasi)	21 40	64 51	297·7	12·16	1	3·9 10·8	6·695	L.
			297·7	12·00	1	...	7·865	L.
			298·8	12·45	3	...	8·712	L.
β 989 A.B.... (κ Pegasi)	21 40	64 51	[illegible]	0·12	3	3·9 5·0	6·518	L.
			75·0	0·06	3	...	6·765	L.
			27·0	0·09	4	...	7·570	L.
			16·6	...	1	...	7·768	L.
			4·8	...	1	...	7·800	D.
			342·0	...	1	...	7·901	L.
			312·2	0·29	1	...	8·605	L.
			298·1	0·25	2	...	8·708	L.
			291·7	0·32	1	...	8·843	W.B.
			287·8	0·39	1	...	8·917	W.B.
			286·0	0·29	2	...	8·932	L.
Σ 2825 ...	21 41	89 42	120·3	0·91	1	8 9	8·920	B.
β 75 ...	21 50	79 35	40·0	1·05	2	8·1 8·3	6·832	L.
			37·6	1·01	1	...	6·827	W.B.
			40·4	1·07	2	...	8·731	W.B.
Σ 2849 ...	21 53	70 19	...	0·87	1	8·2 10·7	6·827	L.
			265·6	1·40	2	...	8·731	W.B.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1890 +	Obs.
*	21 53	69 42	92·3	3·60	1	10·0 11·0	6·827	L.
β 699 ...	22 8	82 50	186·3	0·96	1	8·0 12·0	6·805	L.
Σ 2878 ...	22 9	82 33	123·0	1·37	1	6·5 8·0	6·805	W.B.
			126·9	1·37	2	...	6·816	L.
			122·8	1·26	2	...	7·657	W.B.
			126·9	1·32	1	...	8·717	W.B.
			133·6	1·21	2	...	8·757	B.
Σ 2881 ...	22 10	60 57	99·3	1·72	3	7·7 8·2	6·792	L.
			99·2	1·57	4	...	7·751	W.B.
			101·6	1·61	2	...	8·653	L.
			97·8	1·38	2	...	8·678	W.B.
			97·7	1·75	1	...	8·838	B.
β 1216 ...	22 15	61 2	314·5	0·46	2	8·4 8·7	6·735	L.
			311·4	0·35	1	...	7·764	L.
			310·9	0·54	1	...	7·694	W.B.
			314·2	0·54	3	...	8·675	L.
Σ 2900 ...	22 19	69 40	178·6	1·80	1	6·0 9·2	6·750	C.
			183·9	1·48	2	...	6·787	D.
			179·5	1·36	1	...	6·805	L.
			177·4	—	1	...	6·805	W.B.
			180·1	1·47	1	...	7·737	L.
			183·3	1·74	1	...	7·972	W.B.
			173·3	1·17	3	...	8·789	W.B.
			177·8	1·51	1	...	8·838	B.
β 172 ...	22 19	95 23	10·5	0·88	2	5·6 6·0	8·788	B.
β 1218 ...	22 23	60 52	52·1	1·72	1	8·6 8·8	6·728	L.
			55·2	1·46	2	...	6·865	W.B.
			55·2	1·53	4	...	7·677	W.B.
			54·6	1·61	1	...	7·764	L.
			50·8	1·59	3	...	8·675	L.
			52·2	1·48	2	...	8·678	W.B.
Σ 2912 ...	22 25	86 6	117·8		1	6·5 7·8	7·890	L.
			119·6	0·27	2	...	8·885	L.
			124·2	0·51	1	...	8·953	B.
Σ 2934 ...	22 37	69 6	144·9	0·96	1	8·2 9·2	6·730	D.
			146·9	0·92	1	...	6·750	C.
			144·5	0·78	4	...	8·777	W.B.
			141·5	0·77	1	...	8·816	B.

[redacted]

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1890+	Obs.
	h m	° ′	°	″				
β 1144 B.C. (η Peg.)	22 38	60 18	82·9	0·24	1	10 10	7·764	L.
			90·0	0·36	3	...	8·675	L.
β 710 ...	22 38	60 52	237·8	0·47	1	8·0 8·5	7·764	L.
			235·1	0·39	3	...	8·675	L.
β 711 ...	22 40	79 20	46·4	0·72	1	9 10	7·758	W.B.
			39·6	—	1	...	7·972	B.
			42·7	1·00	1	...	8·734	W.B.
			45·1	1·00	1	...	8·794	B.
			39·8	0·82	1	...	8·890	L.
Σ 2944 A.B.	22 42	94 47	261·8	3·52	1	7·0 7·5	7·871	B.
			259·9	3·41	1	...	8·745	W.B.
			255·4	3·49	1	...	8·775	B.
A.C.	...	...	131·1	47·82	1	7·0 8·0	8·775	B.
β 1146 ...	22 43	59 26	331·1	0·19	1	7·2 8·2	7·800	L.
β 382 ...	22 49	45 47	223·8	0·73	1	7·3 8·8	6·558	L.
			225·7	0·97	1	...	7·819	D.
			225·1	0·64	1	...	7·966	W.B.
O Σ 536 ...	22 53	81 10	185·9	0·32	1	7·3 7·4	6·827	L.
O Σ 483 ...	22 53	78 48	217·6	0·92	1	6·0 7·5	6·709	D.
			209·8	1·08	3	...	6·806	C.
			213·3	0·99	1	...	6·827	L.
Ho. 64 ...	23 2	68 54	86·1	0·37	1	7 7	7·975	L.
Σ 2995 ...	23 12	92 4	28·8	4·91	2	7·7 8·0	8·805	W.B.
β 80 ...	23 13	85 9	330·0	0·60	1	8·1 8·7	8·778	W.B.
			339·6	0·51	1	...	8·994	B.
β 1222 ...	23 23	87 0	31·8	1·04	1	9 9	8·745	W.B.
Σ 3018 A.C.	23 25	59 53	25·6	19·01	1	7·2 9·0	6·717	L.
			25·2	18·98	1	...	7·953	L.
			21·2	18·86	1	...	8·701	L.
β 1266 A.B.	23 25	59 53	232·0	0·28	2	7·2 7·5	6·778	L.
			221·6	0·36	1	...	7·944	L.
			234·0	0·35	1	...	8·711	L.
β 720 ...	23 29	59 14	157·7	0·37	3	5·5 5·5	6·761	L.
			164·5	0·43	1	...	7·819	D.
			160·2	0·33	2	...	7·927	L.
			158·2	0·50	1	...	8·780	L.
			159·2	0·39	1	...	8·909	W.B.
			151·1	0·34	1	...	8·969	B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1890+	Obs.
	h m	° ′	°	″				
β 858 ...	23 36	58 0	268·0	0·61	1	8·0 8·2	6·717	L.
			261·9	0·67	3	...	7·790	W.B.
			269·6	0·71	1	...	7·819	D.
			267·1	0·75	1	...	8·726	L.
			267·4	0·81	1	...	8·868	W.B.
A.G.C. 14 ...	23 29	61 12	215·9	1·17	1	5·5 9·7	6·704	W.B.
			202·9	1·28	1	...	6·838	L.
			194·5	1·55	1	...	7·739	W.B.
			195·0	1·48	1	...	7·953	L.
			195·8	1·39	2	...	8·740	W.B.
			190·2	1·49	1	...	8·868	L.
β 1223 ...	23 40	85 29	294·8	1·19	1	8 11	7·958	L.
Barnard ...	23 42	85 18	161·8	0·37	1	8·6 8·6	7·958	L.
Σ 3050 ...	23 54	56 51	211·9	2·79	3	6·0 6·0	6·736	W.B.
			210·0	...	...	...	7·871	B.
			212·7	2·25	2	...	7·921	W.B.
			213·0	2·58	3	...	8·931	B.
β 733 A.B.	23 57	63 26	216·1	0·76	1	6·0 11·0	7·975	L.
			225·5	0·59	2	...	8·796	L.
β 281 ...	23 58	88 26	203·3	1·53	1	8 10	7·958	L.
Σ 3056 ...	23 59	56 20	147·0	0·50	2	7 8	7·870	W.B.
			145·5	0·46	1	...	7·953	L.
			149·8	0·63	3	...	8·921	B.
			151·3	0·70	1	...	8·948	W.B.

Double Star Observations, 1897–98. By J. L. Scott.

The following measures of Southern double stars were made with a 5-inch equatorial refractor, O.G. by Casella, mounting by T. Cooke & Sons. The double parallel wire micrometer is also by these makers, the value of one revolution of the screw, as determined by transits of circumpolar stars, being 24″·180.

Bright field illumination.

Star's Name.	Mags.	R.A.	S. Dec.	P.A.	Distance.	Date.	Power.
		h m	° ′	°	″	1890 +	
β 391 (κ′ Sculptoris)	6½, 6½	0 4	28 33	272·2	1·15	7·936	230
				270·5	1·20	7·939	,,
				270·9	1·08	7·967	,,
				271·3	1·00	7·975	,,
				271·2	1·11		
h 1957	7, 8½	0 17	23 34	23·4	6·09	7·923	162
				21·6	6·20	7·931	,,
				22·5	6·15		
Ll 1662... ...	7½, 7½	0 53	16 15	216·4	6·58	7·904	162
				215·5	6·43	7·906	,,
				216·0	6·50		
Σ 91 (Ll 1965)	7½, 8½	1 02	2 18	322·4	4·23	7·745	230
				320·5	4·11	7·747	,,
				321·9	4·38	7·750	,,
				321·6	4·24		
42 Ceti (Σ 113)	6½, 7½	1 14	1 1	354·9	1·20	7·747	230
				353·5	1·32	7·750	,,
				354·2	1·26		
h 2036	7½, 7½	1 15	16 20	16·4	1·52	7·887	230
				15·9	1·60	7·904	,,
				16·8	1·57	7·917	,,
				16·4	1·56		
A.G.C. 1299 ...	6½, 8¾	1 16	19 44	74·9	5·22	7·747	162
				74·8	5·12	7·767	,,
				74·9	5·17		

Star's Name.	Mags.	R.A.	S. Dec.	P.A.	Distance.	Date.	Power.
		h m	° ′	°	″	1890 +	
β 745 (λ Sculptoris)	6, 8	1 31	30 26	94·8	1·80	7·904	230
				93·7	1·86	7·912	,,
				93·9	1·94	7·923	,,
				94·1	1·87		
Lac 485... ...	7½, 8	1 34	38 6	274·8	19·55	7·904	162
				274·9	18·95	7·906	,,
				274·9	19·25		
Σ 147	5½, 7½	1 37	11 50	87·2	3·92	7·887	162
				86·3	4·18	7·893	,,
				86·8	4·05		
229 Ceti ...	7, 7½	1 54	23 24	306·2	8·12	7·893	162
				306·4	8·49	7·904	,,
				306·3	8·30		
Ll 4219... ...	8, 8½	2 10	18 47	346·1	1·98	7·887	230
				346·6	2·04	7·904	,,
				346·4	2·01		
Σ 280	8, 8	2 28	6 10	348·9	3·63	7·917	162
				348·6	3·76	7·923	,,
				348·8	3·70		
h 3506	5, 8	2 29	28 40	243·9	10·60	7·904	162
				245·6	10·40	7·906	,,
				244·8	10·50		
h 3532	6½, 8½	2 44	37 50	148·7	5·05	7·904	162
				149·3	5·42	7·906	,,
				149·0	5·29		
θ Eridani ...	3, 4	2 54	40 43	85·7	8·60	7·936	105
				84·9	8·52	7·939	,,
				85·2	8·58	7·945	,,
				85·3	8·57		
h 3555 (12 Eridani)	3, 8	3 8	29 23	328·2	1·70	7·895	230
				330·5	1·55	7·912	,,
				329·4	1·63		

Star's Name.	Mags.	R.A.	S. Dec.	P.A.	Distance.	Date.	Power.
		h m	° ′	°	″	1890 +	
h 3565	5¾, 8½	3 14	18 56	115·4	6·10	7·904	162
				115·7	6·29	7·906	"
				115·6	6·20		
h 3597 (f Eridani)	4¾, 5¼	3 45	37 56	205·1	7·30	7·912	162
				205·7	7·42	7·917	105
				205·4	7·36		
h 3611	7, 7½	3 53	40 16	142·9	4·05	7·901	162
				143·4	4·20	7·906	"
				143·2	4·13		
40 Eridani (A B)	4, 9	4 10	7 47	105·4	82·40	7·912	105
				105·1	82·10	7·917	"
				105·3	82·25		
Ll 8521... ...	7, 9	4 24	25 28	351·5	6·75	7·936	162
				352·4	6·52	7·939	105
				351·9	6·88	7·945	"
				351·9	6·72		
33 Orionis ...	6, 8	5 25	N. 3 12	26·3	1·75	7·939	230
				25·4	2·05	7·967	"
				25·7	1·88	7·975	"
				25·8	1·89		
52 Orionis ...	6, 6½	5 42	N. 6 28	208·4	1·40	8·008	230
				208·3	1·52	8·011	"
				209·0	1·35	8·016	"
				208·5	1·42		
β 201 (Ll 14925)	7, 8	7 33	20 0	333·2	2·85	8·096	230
				332·6	2·70	8·110	"
				332·9	2·78		
β 210	6½, 6½	8 51	16 58	183·7	2·50	8·085	230
				183·2	2·56	8·096	"
				183·5	2·62	8·110	"
				183·5	2·56		
Σ 1788	7, 8½	13 48	7 31	77·6	2·80	8·416	230
				75·1	3·01	8·419	"
				77·7	3·20	8·424	"
				76·8	3·00		

Star's Name.	Mags.	R.A.	S. Dec.	P.A.	Distance.	Date.	Power.
		h m	° ′	°	″	1890 +	
β 106 (μ Libræ)	5½, 6½	14 42	13 39	345·1	1·60	8·416	230
				344·4	1·56	8·419	„
				344·8	1·58		
P xiv. 212 ...	6, 8	14 50	20 53	293·3	15·84	8·416	162
				293·1	16·20	8·419	„
				293·2	16·02		
β 350 (B.A.C. 5020)	6½, 8	15 10	27 13	156·2	1·40	8·485	230
				154·8	1·15	8·496	„
				156·6	1·18	8·498	„
				155·9	1·24		
h 4755	8, 9	15 13	36 20	201·8	4·42	8·496	162
				202·5	4·11	8·498	„
				202·2	4·27		
β 122	7, 7½	15 34	19 27	208·5	1·90	7·490	230
				207·4	1·78	7·493	„
				208·0	1·84		
β 36 (2 Scorpii)	5, 9	15 47	25 2	275·4	2·85	8·482	230
				274·2	3·00	8·496	„
				276·8	2·78	8·501	„
				275·5	2·88		
η Lupi	4, 8½	15 53	38 6	20·4	14·65	8·465	162
				20·8	14·90	8·468	„
				20·6	14·78		
Stone 8722 ...	7½, 8	15 57	32 47	344·8	2·90	8·496	230
				345·2	..	8·501	„
				346·3	3·05	8·504	„
				345·0	2·92	8·509	„
				345·3	2·96		
ξ Scorpii (A B)	4½, 5	15 58	11 4	212·5	Elongated	7·482	230
				218·0	„	7·487	„
				215·0	„	7·490	„
				216·0	„	7·493	„
				217·1	„	7·496	„
				215·7	...		

Star's Name.	Magn.	R.A.	S. Dec.	P.A.	Distance.	Date.	Power.
		h m	° ′	°	″	1890 +	
ν Scorpii (C D)	7, 8	16 5	19 10	49·0	2·00	7·482	230
				48·2	2·05	7·487	,,
				48·9	2·02	7·490	,,
				48·7	2·02		
h 4840	8, 9	16 10	34 35	297·2	4·84	8·501	162
				297·9	5·15	8·504	,,
				297·6	5·00		
h 4889	6, 9	16 44	37 20	6·8	6·95	7·482	162
				7·3	7·06	7·487	,,
				7·0	7·00		
β 416	6, 8	17 12	34 53	310·8	1·54	7·446	230
				308·7	...	7·452	,,
				310·6	2·00	7·463	,,
				309·6	1·98	7·468	,,
				307·0	1·63	7·479	,,
				310·7	...	7·482	,,
				305·2	...	7·490	,,
				307·9	1·86	7·496	,,
				308·8	1·80		
Stone 9723 (A.G.C. 24226)	7, 8	17 43	30 31	[illegible]	10·25	7·490	162
				190·8	10·50	7·493	,,
				189·5	10·38		
70 Ophiuchi ..	4, 6	18 0	N. 2 33	284·4	2·10	7·487	230
				281·7	2·05	7·490	,,
				283·2	2·18	7·496	,,
				285·1	2·05	7·498	,,
				282·8	2·20	7·507	,,
				283·5	2·08	7·512	,,
				283·5	2·11		
				274·0	2·15	8·468	230
				269·9	2·38	8·487	,,
				271·3	2·10	8·545	,,
				272·6	2·25	8·548	,,
				273·3	2·35	8·550	,,
				272·2	2·25		

Star's Name.	Mags.	R.A.	S. Dec.	P.A.	Distance.	Date.	Power.
		h m	° ′	°	″	1890 +	
β 132 (B.A.C. 6158)	7, 7½	18 4	19 52	222·0	Elongated	7·594	230
				226·0	,,	7·619	,,
				224·0	...		
21 Sagittarii (Jacob 201)	5, 9½	18 19	20 36	286·9	1·68	8·542	230*
				289·4	1·89	8·545	,,
				287·2	...	8·548	,,
				287·9	1·70	8·550	,,
				287·8	1·76		
β 133	7½, 7½	18 22	26 42	259·4	1·87	7·493	230
				260·5	1·57	7·498	,,
				258·1	1·80	7·501	,,
				259·3	1·75		
γ Cor. Australis	5½, 5½	18 59	37 13	155·3	1·60	7·446	230
				154·3	1·74	7·452	,,
				154·8	1·52	7·455	,,
				154·8	1·62		
				148·9	1·94	8·550	230
				151·5	1·79	8·556	,,
				147·6	1·84	8·564	,,
				146·8	2·02	8·575	,,
				148·6	1·95	8·589	,,
				148·7	1·91		
h 596 (LI 36205)	7, 8	19 10	16 11	14·2	8·82	7·490	162
				13·3	8·68	7·493	,,
				13·8	8·44	7·498	,,
				13·8	8·65		
β 142	8, 8	19 22	12 21	332·7	1·45	7·687	230
				333·2	1·68	7·693	,,
				330·8	1·30	7·695	,,
				334·2	1·70	7·698	,,
				332·7	1·53		
				333·3	1·50	8·641	230
				333·7	1·60	8·668	,,
				333·5	1·55		

* Companion extremely faint and difficult.

Star's Name.	Magn.	R.A.	S. Dec.	P.A.	Distance.	Date.	Power.
		h m	° ′	°	″	1890 +	
h 5178 (Stone 10831)	7, 8½	20 6	34 29	9·4	3·14	7·616	230
				10·3	2·93	7·619	„
				9·9	3·04		
β 762 (Stone 10844)	7, 8	20 10	32 55	302·8	2·56	7·616	230
				304·7	2·42	7·619	„
				303·8	2·49		
h 1537 … …	8½, 8½	20 29	15 44	23·0	4·00	7·693	162
				22·7	3·80	7·695	„
				22·5	4·15	7·698	„
				22·7	3·98		
β 153 … …	7½, 10	20 41	26 47	273·4	1·70	7·624	230*
				273·0	…	7·635	„
				272·7	1·40	7·682	„
				273·0	1·55		
h 3003 … …	6, 9	20 47	24 10	213·7	2·05	7·611	230
				216·2	2·30	7·616	„
				215·6	2·20	7·619	„
				215·2	2·18		
A. G. C. 29052 …	8, 9	21 4	23 37	302·1	9·91	7·641	162
h 3014 (Stone 11268)	8, 8	21 9	26 20	298·0	1·80	7·633	230
				297·0	1·92	7·635	„
				296·3	2·00	7·641	„
				297·1	1·91		
β 252 … …	8½, 8½	21 14	27 45	276·1	2·50	7·742	230
				277·5	2·60	7·745	„
				276·8	2·55		
η Piscis Australis	6, 7	21 55	28 56	115·8	1·67	7·616	230
				115·5	1·70	7·619	„
				115·8	1·72	7·624	„
				115·8	1·70		
				115·9	1·60	8·641	230
				116	1·94	8·668	„
				115·7	1·86	8·671	„
				115·9	1·80		

* Companion extremely faint.

Star's Name.	Magn.	R.A.	S. Dec.	P.A.	Distance.	Date.	Power.
		h m	° ′	°	″	1890 +	
41 Aquarii ...	6½, 8½	22 9	21 34	116·0	5·08	7·742	162
				115·8	5·30	7·745	,,
				115·9	5·19		
53 Aquarii ...	6½, 6½	22 20	17 18	309·0	7·31	7·887	162
				308·6	7·18	7·893	,,
				308·8	7·25		
ζ Aquarii ...	4, 4½	22 23	0 32	321·8	3·30	8·641	162
				319·3	3·38	8·668	,,
				319·6	3·22	8·671	,,
				320·2	3·30		
Σ 2928	8, 8½	22 34	13 10	313·2	4·57	7·641	162
				313·7	4·40	7·643	,,
				313·4	4·49		
Σ 2935	6½, 8½	22 37	8 50	313·6	2·70	7·682	230
				312·8	2·66	7·685	,,
				313·2	2·68		
β 177	8½, 8½	22 46	22 20	277·8	2·20	7·676	230
				276·5	2·24	7·682	,,
				277·2	2·10	7·685	,,
				277·2	2·18		
h 5367 (γ Pisc. Austral.)	5, 8	22 47	33 24	269·5	3·70	7·912	162
				267·8	3·45	7·920	230
				268·7	3·58		
h 5371 (A.G.C. 31221)	7½, 9	22 52	26 38	343·9	9·17	7·676	162
θ Gruis	5, 8	23 1	44 4	24·1	2·80	7·917	230
				26·8	2·20	7·920	,,
				25·5	2·50		
Σ 2988	7, 7½	23 6	12 27	101·3	3·70	7·887	230
				101·0	3·62	7·893	162
				101·2	3·66		
Σ 2998 (94 Aquarii)	6, 8½	23 13	14 2	349·9	12·94	7·742	162
				349·8	13·28	7·745	,,
				349·9	13·11		

Star's Name.	Mags.	R.A.	S. Dec.	P.A.	Distance.	Date.	Power
		h m	° ′	°	″	1890 +	
h 3184	7, 8½	23 15	19 12	282·3	5·80	7·619	162
				283·0	5·15	7·641	„
				282·7	5·48		
Σ 3008	8, 8½	23 18	9 2	244·3	4·40	7·923	162
				244·1	4·35	7·931	„
				244·2	4·38		
ι^{3} Aquarii ...	5½, 7	23 41	19 14	138·5	5·80	7·742	162
				139·1	5·94	7·745	„
				138·8	5·87		
Brisbane 7342 ...	6, 6½	23 49	27 36	269·9	6·31	7·917	162
				269·6	6·55	7·931	„
				269·8	6·43		
Σ 3046	8, 8½	23 50	10 10	245·6	3·05	7·687	162
				248·7	2·95	7·693	„
				247·2	3·00		

Shanghai :
1898 *December.*

Erratum.

Vol. lix., p. 297, *dele* line 5 from bottom.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

Vol. LIX. May 12, 1899. No. 8.

Professor G. H. Darwin, M.A., LL.D., President, in the Chair.

Rev. Edward Lyon Berthon, M.A., St. Margaret's, Cupernham, Romsey, Hants; and
Rev. Theodore Evelyn Reece Philips, M.A., Handford Vicarage, Yeovil, Somerset,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Rev. Thomas Gerrard Barber, B.A., 10 Highfield Road, Doncaster (proposed by J. W. L. Glaisher); and
Sydney Samuel Hough, B.A., Chief Assistant, Royal Observatory, Cape of Good Hope (proposed by David Gill).

The following were proposed by the Council as Associates of the Society :—

G. E. Hale, D.Sc., F.R.A.S., Director of the Yerkes Observatory, Williams Bay, Wisconsin, U.S.A.;
F. R. Helmert, Director of the Geodetic Institute, Potsdam, Germany;

F. Kustner, Director of the Observatory, Bonn, Germany; and

Juan M. Thome, Director of the Argentine National Observatory, Cordoba, Argentine Republic.

Eighty-two presents were announced as having been received since the last meeting, including, amongst others: —

G. H. Darwin, The Tides, presented by the author; Bordeaux Observatory, Annales, tome 8; and Munich Observatory, Neue Annalen, Band 3, presented by the Observatories.

On the Errors of Star Photographs due to Optical Distortion of the Object-glass with which the Photograph is taken. By H. H. Turner, M.A., F.R.S., Savilian Professor.

1. When the International Conference assembled in 1887 to consider the construction of a chart of the heavens by photography, the most important question which met them at the outset was, With what kind of instrument should the work be done? Possible instruments were the reflector, the refractor with achromatic object-glass, and the photographic doublet. The achromatism of the first-named, a great advantage in photographic work, was overbalanced by its strictly limited field, and certain inconveniences of working; the large field of the photographic doublet was regarded with suspicion, suggesting possibilities of complex optical distortion; and the simple photographic refractor was chosen. We have learnt a good deal more about stellar photography since 1887; and I would now venture the opinion that, though the choice of the simple refractor has been attended with many advantages, especially in the taking, measurement, and reduction of the "Catalogue" plates, the photographic doublet is the proper instrument for *charting* purposes. The fears about optical distortion are to a large extent groundless, as the present paper will show; and the advantages of getting a large field are too obvious to need explanation In this opinion I am, of course, only following at a respectful distance Professor E. C. Pickering, who urged the claims of the doublet on the Conference in 1887, and who has continued to work with various forms of the doublet ever since. But I have not seen published any attempt to show that the optical distortion of the doublet is small, and though the present investigation leaves much to be desired, it will to some extent fill this gap.

2. For examination of the optical distortion of a doublet Professor E. C. Pickering kindly sent to Oxford some positive copies of large plates (16 inches by 13 inches) taken at Arequipa with the Bruce doublet of the same focal length as the instruments used for the Astrographic Chart, viz., $11\frac{1}{4}$ feet, so that 1^{mm} on the plate corresponds to $1'$. A simple and direct way to examine the distortion would be to put a *réseau* on this plate (or on a copy of it) and measure the positions of known stars in different parts of the plate; but our measuring instruments, *réseaux*, &c., at Oxford are only adapted to plates of $2° \times 2°$, and this direct process is unfortunately not feasible. As an alternative, contact-negatives of different portions of the large positive were made on plates of the $2° \times 2°$ size, and compared with plates of exactly the same regions taken with the Oxford astrographic telescope. Thus we must first show that these latter plates are free from distortion.

The Oxford plates for the Astrographic Catalogue are free from optical distortion. §§ 3-11.

3. The process of measuring and reducing a catalogue plate has been several times described. Rectangular coordinates (x, y) of the stars on the plate are obtained by referring them to the *réseau*. If

(*a*) The focal length of the telescope were such that $1^{mm} = 1'$ exactly; and the telescope in exact adjustment;
(*b*) The plate were correctly oriented in the telescope;
(*c*) There were no refraction and aberration;
(*d*) The plate were flat, and normal to the line of collimation;
(*e*) The *réseau* were perfect;
(*f*) The lens had no optical distortion;

then these (x, y) coordinates would be the same as what have been called "standard coordinates" (ξ, η) connected with R.A. and N.P.D. by the formulæ

$$\mu\xi = \tan(\alpha - A)\sin q\sec(P-q),\ \mu\eta = \tan(P-q) \quad . \quad . \quad . \quad . \quad (1)$$

where (α, p) are the R.A. and N.P.D. of the star,
(A. P.) are the R.A. and N.P.D. of the plate-centre,

$$\tan q = \tan p \cos(\alpha - A),$$

and μ is the circular measure of $5'$.

4. Further, the sources of error indicated in (*a*), (*b*), (*c*) may be eliminated by assuming linear relations of the form

$$\xi = x + ax + by + c \qquad \eta = y + dx + ey + f \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

For certain stars on the plate the R.A. and N.P.D., and hence ξ and η, are known; and when these have been measured so as to determine the x and y for them, from a set of equations such as (2), we can determine a, b, c, d, e, f. To determine these six constants, three known stars (giving three pairs of equations) are

theoretically enough; but, owing to the existence of accidental errors, it is advisable to use as many stars as possible of which the R.A. and N.P.D. are known.

5. For the main part of the work assigned by the International Committee to the Oxford University Observatory, viz., zones $+25°$ to $+31°$, the "known" stars are taken from the meridian observations made at Cambridge in the years 1872 to 1896, in revision of Argelander's zones for the *Astronomische Gesellschaft* Catalogue. These observations give us an average of about 30 "known" stars on a plate, from which the constants a, b, c, d, e, f are determined, the actual process adopted being to group all the stars in the

N. half, S. half, E. half, W. half

of the plate, and take the mean in each case. Were the stars symmetrically distributed, this would give us eight equations of the form

$$\left.\begin{array}{ll} 0{\cdot}a + 19{\cdot}5b + c = r_1 & 0{\cdot}d + 19{\cdot}5e + f = R_1 \\ 0{\cdot}a + 6{\cdot}5b + c = r_2 & 0{\cdot}d + 6{\cdot}5e + f = R_2 \\ 19{\cdot}5a + 0{\cdot}b + c = r_3 & 19{\cdot}5d + 0{\cdot}e + f = R_3 \\ 6{\cdot}5a + 0{\cdot}b + c = r_4 & 6{\cdot}5d + 0{\cdot}e + f = R_4 \end{array}\right\} \quad . \quad . \quad (3)$$

So that

$$\left.\begin{array}{ll} a = (r_3 - r_4)/13, & b = (r_1 - r_2)/13 \\ d = (R_3 - R_4)/13, & e = (R_1 - R_2)/13 \end{array}\right\} \quad . \quad . \quad . \quad . \quad (4)$$

Substituting the values of a and b in each of the first set we get four values for c, which ought to agree if the arithmetic is correct (though the agreement is no check on the accuracy of the measures, for the four equations are not independent, and are really equivalent to three only).

In practice the stars are, of course, not symmetrically distributed, and the equations only approximate to this form: but the method of solution is the same.

6. When a, b, c, d, e, f have been obtained, the values of $x + ax + by + c - \xi$ and $y + dx + ey + f - \eta$ are formed for the individual stars and called residuals. Now these residuals are affected with the errors indicated in (d), (e), (f) above, viz.:

(d) Curvature of the plate and tilt.
(e) Errors of the *réseau*.
(f) Optical distortion of the lens

as well as by

(g) Errors of the meridian observations, and proper motions of the stars.

If we collect the residuals for a number of plates, and group them according to position of the star with reference to the centre of the plate, then errors (g) may be regarded as purely

accidental, and the same in all portions of the plate. It is probable also that the curvature of the plates may be treated as accidental in its effects, though of course it is not impossible that there may be a systematic curvature in all photographic plates leading to small systematic errors in the observations; but these would be very small indeed—the errors of errors—for in making the measures the curvature of the plate is corrected for in the correction for "runs"; and we can sensibly neglect errors from this cause.

7. Thus in the mean of a number of plates we should have the residuals affected systematically by

(A) Optical distortion and tilt of the plate.
(B) Errors of the *réseau*.

The latter might be separately determined, but this work has not yet been undertaken, as it is known that the *réseau* errors are very small. Moreover, in the measures collected below several different *réseaux* were used, and the errors would tend to compensate. The means given below may thus be regarded as showing optical distortion of the lens and tilt of the plate, if any.

8. The 40 plates examined were in $+26°$, 18^h-24^h, and thus had a good many stars on them. They were grouped in hours of R.A., viz.: 8 plates in 18^h, 5 plates in 19^h, 7 in 20^h, 5 in 21^h, 8 in 22^h, 7 in 23^h.

Each plate was divided into 16 portions, exclusive of narrow strips enclosing the coordinate axes omitted for convenience; viz., each coordinate running from 0 to 26, the 16 portions were obtained by grouping together portions

$$0{\cdot}0-6{\cdot}0,\ 6{\cdot}0-12{\cdot}0,\ 14{\cdot}0-20{\cdot}0,\ 20{\cdot}0-26{\cdot}0$$

in each coordinate, so that the mean coordinates of the groups referred to the centre of the plate were approximately

$x=-10{\cdot}0$	$-\ 4{\cdot}0$	$+\ 4{\cdot}0$	$+10{\cdot}0$
$y=+10{\cdot}0$	$+10{\cdot}0$	$+10{\cdot}0$	$+10{\cdot}0$
$x=-10{\cdot}0$	$-\ 4{\cdot}0$	$+\ 4{\cdot}0$	$+10{\cdot}0$
$y=+\ 4{\cdot}0$	$+\ 4{\cdot}0$	$+\ 4{\cdot}0$	$+\ 4{\cdot}0$
$x=-10{\cdot}0$	$-\ 4{\cdot}0$	$+\ 4{\cdot}0$	$+10{\cdot}0$
$y=-\ 4{\cdot}0$	$-\ 4{\cdot}0$	$-\ 4{\cdot}0$	$-\ 4{\cdot}0$
$x=-10{\cdot}0$	$-\ 4{\cdot}0$	$+\ 4{\cdot}0$	$+10{\cdot}0$
$y=-10{\cdot}0$	$-10{\cdot}0$	$-10{\cdot}0$	$-10{\cdot}0$

the strip 12·0 to 14·0 in each coordinate being omitted. The average number of stars in each group was 20. The groups are given separately as an indication of the probable error of a

determination. It will be noticed that the x residuals are larger than the y residuals, indicating that the Cambridge observations of N.P.D. are more accurate than those of R.A., for of course there is no difference in the photographic measures.

9. The unit adopted in the following table is ·0001 of a *réseau* interval or 0″·03. The largest mean residual, 24, thus represents 0″·72.

Mean Residuals of Groups.

	In x.				In y.			
18ʰ	13	+ 7	+ 13	− 2	− 1	0	− 1	5
19ʰ	+ 4	− 9	+ 8	− 19	+ 1	+ 1	− 8	− 8
20ʰ	− 4	+ 12	− 8	− 9	− 6	− 2	− 3	+ 2
21ʰ	− 9	− 14	− 15	− 2	+ 3	+ 4	− 2	+ 6
22ʰ	− 15	+ 1	− 4	− 9	− 6	− 2	− 8	+ 12
23ʰ	+ 8	+ 24	+ 1	+ 11	+ 15	− 10	+ 26	+ 2
Mean	− 5	+ 4	− 1	− 5	+ 1	− 2	+ 1	+ 2
18ʰ	+ 8	− 13	− 6	+ 11	− 5	− 7	− 4	− 2
19ʰ	+ 11	+ 16	+ 18	+ 5	+ 1	+ 14	+ 12	− 1
20ʰ	+ 2	+ 11	− 1	− 24	− 1	− 3	− 3	+ 2
21ʰ	+ 15	+ 7	− 2	0	+ 2	− 8	− 4	− 2
22ʰ	+ 3	− 2	+ 10	− 2	− 1	− 8	− 12	+ 7
23ʰ	− 3	− 21	+ 15	− 4	− 13	− 1	+ 3	− 12
Mean	+ 6	0	+ 6	− 2	− 3	− 2	− 1	− 1
18ʰ	4	+ 22	− 4	− 12	0	+ 5	− 2	− 3
19ʰ	− 9	+ 7	− 11	+ 2	0	+ 1	− 6	0
20ʰ	− 12	− 4	+ 15	− 14	+ 4	+ 3	+ 2	0
21ʰ	− 4	+ 3	+ 4	− 7	+ 6	+ 4	− 3	+ 9
22ʰ	+ 3	− 7	+ 6	− 2	+ 9	− 6	− 10	+ 15
23ʰ	+ 2	− 11	− 20	+ 28	+ 6	+ 13	+ 4	− 11
Mean	− 4	+ 2	− 2	− 1	+ 4	+ 3	− 3	+ 2
18ʰ	− 12	+ 9	0	− 15	3	+ 4	− 11	+ 1
19ʰ	− 11	− 25	+ 9	+ 3	4	+ 2	+ 5	+ 2
20ʰ	+ 2	+ 6	+ 18	0	13	+ 6	+ 4	− 7
21ʰ	− 9	− 10	+ 5	+ 20	+ 4	− 3	− 3	− 9
22ʰ	− 1	+ 10	+ 9	+ 2	+ 4	+ 2	+ 5	− 8
23ʰ	− 4	+ 22	0	+ 2	+ 9	+ 3	− 6	− 9
Mean	− 6	+ 2	+ 7	+ 2	0	+ 2	− 1	− 5

10. The sum of the x residuals without regard to sign is 848, and of the y residuals 511, giving a ratio of 1·66 for the probable

errors. The sum of the mean of group residuals is similarly 55 for x and 33 for y, giving a ratio of 1·67. Thus the y observations are more accurate. Since either coordinate would equally well reveal any optical distortion or tilt, we may rest satisfied that these errors are at least as small as is indicated by the y residuals, which are less affected by accidental errors. It may be well to repeat the means for all the plates for y in the more familiar unit of seconds of arc, as below.

$+0''.03$	$-0''.06$	$+0''.03$	$+0''.06$
-0.09	-0.06	-0.03	-0.03
$+0.12$	$+0.09$	-0.09	$+0.06$
0.00	$+0.06$	-0.03	-0.15

11. I think it will be admitted that measures capable of giving such means are sensibly free from systematic errors, whatever the accidental errors may be. It should perhaps be repeated here that the measures are made with scales divided only to $3''.0$, and reading by estimation to $0''.3$, so that the largest of the above residuals, $0''.15$, is only half the unit of measurement.

The x residuals, though rougher, never reach the unit of measurement.

Two plates with different centres. §§ 12–21.

12. When two plates are taken with centres at the same point of the heavens (the "centre" meaning in this connection the foot of the normal from the centre of the object-glass on the plate), then coordinates on one are connected by simple linear relations with coordinates on the other, whatever may be the differences of scale orientation, refraction, aberration, &c. But for plates with different centres the relations are no longer linear, though, since the centres are not far apart whenever stars are common to both plates, the non-linear terms are small. If $(x_1\ y_1)$ are the coordinates of a star on one plate, and $(x_2\ y_2)$ those of the same star on the other, and if, further, (X Y) be the coordinates of the centre of plate 2 on plate 1, then

$$x_2 + (\mathrm{X}x_2x_1 + \mathrm{Y}x_2y_1)\mu^2, \text{ and } y_2 + (\mathrm{X}x_1y_2 + \mathrm{Y}y_1y_2)\mu^2,$$

where μ is the circular measure of $5'$, are linear functions of x_1 and y_1. A proof of this proposition has already been given; the following is another which represents the relations from a slightly different point of view.

13. Let $(l_1\ m_1\ n_1)$, $(l_2\ m_2\ n_2)$ be direction-cosines of the same star referred to two different sets of axes. Then the ratios $\left(\frac{\mu l}{n}, \frac{\mu m}{n}\right)$ are in each case what we have called "standard

coordinates" referred to the extremity of the n axis as plate-centre. Further, we know that there are linear relations,

$$\left.\begin{aligned} l_2 &= a_1 l_1 + a_2 m_1 + a_3 n_1 \\ m_2 &= b_1 l_1 + b_2 m_1 + b_3 n_1 \\ n_2 &= c_1 l_1 + c_2 m_1 + c_3 n_1 \end{aligned}\right\} \quad . \quad . \quad . \quad (5)$$

Hence, if we put $\mu\xi = \frac{l}{n}$, $\mu\eta = \frac{m}{n}$, we have

$$\mu\xi_2 = \frac{l_2}{n_2} = \frac{\mu a_1\xi_1 + \mu a_2\eta_1 + a_3}{\mu c_1\xi_1 + \mu c_2\eta_1 + c_3}, \ \mu\eta_2 = \frac{\mu b_1\xi_1 + \mu b_2\eta_1 + b_3}{\mu c_1\xi_1 + \mu c_2\eta_1 + c_3}. \quad . \quad . \quad . \quad (6)$$

The coordinates (X, Y) of the centre of the second plate on the first are given by putting $\xi_2 = 0$, $\eta_2 = 0$.

Hence

$$\left.\begin{aligned} \mu a_1 X + \mu a_2 Y + a_3 = 0 \\ \mu b_1 X + \mu b_2 Y + b_3 = 0 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

and thus

$$\mu X = \frac{a_2 b_3 - a_3 b_2}{a_1 b_2 - a_2 b_1} = \frac{c_1}{c_3}, \ \mu Y = \frac{c_2}{c_3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

by the properties of direction-cosines.

Thus the denominator in the expressions for ξ_2 and η_2 becomes

$$c_3(1 + \mu^2 X\xi_1 + \mu^2 Y\eta_1),$$

and we have, multiplying up by the factor in brackets,

$$\left.\begin{aligned} \xi_2 + \mu^2(X\xi_1\xi_2 + Y\eta_1\xi_2) &= \frac{a_1}{c_3}\xi_1 + \frac{a_2}{c_3}\eta_1 + \frac{1}{\mu}\cdot\frac{a_3}{c_3} \\ \eta_2 + \mu^2(X\xi_1\eta_2 + Y\eta_1\eta_2) &= \frac{b_1}{c_3}\xi_1 + \frac{b_2}{c_3}\eta_2 + \frac{1}{\mu}\cdot\frac{b_3}{c_3}, \end{aligned}\right\} \quad . \quad . \quad (9)$$

14. Thus, to correct ξ_2 and η_2 so that they may be linear functions of ξ_1 and η_1 we must add to each its product by

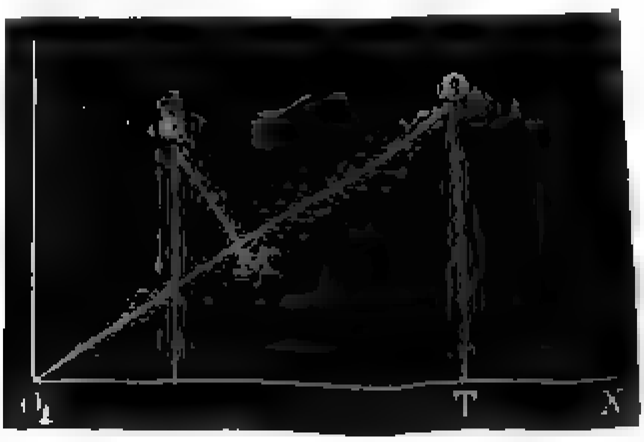


Fig. 1

$\mu^2(X\xi_1 + Y\eta_1)$. The geometrical meaning of this latter quantity is as follows :—Let O_1 be the centre of the first plate, O_1X the

axis of x; O_2 the centre of second plate as projected on the first; and S a star. Then

$$\left.\begin{aligned} X\xi_1 + Y\eta_1 &= O_1S \times O_1O_2 \cos SO_1O_2 \\ &= O_1O_2 \times O_1M \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

where SM is the perpendicular from S on O_1O_2.

The correction is thus directly proportional to (a) the distance between centres of plates; (b) to the abscissæ of stars parallel to the line joining centres; and (c) to the coordinate to be corrected.

15. In the present investigation, in which plates of constant size (2° × 2° approximately) are compared with a large plate which includes them completely, the range of values of this correction varies directly as a, the distance between centres; for of the other two factors, b has nearly the same range, and c exactly the same range in all cases.

16. When the plate centres are near together, as they are in practically dealing with photographs, and the axis of $(\xi_1 \eta_1)$ nearly in the same direction as those of $(\xi_2 \eta_2)$, we may write the corrections

$$X\xi^2 + Y\xi\eta, \quad X\xi\eta + Y\eta^2,$$

where $(\xi \eta)$ denote either $(\xi_1\eta_1)$ or $(\xi_2\eta_2)$, as is most convenient. For $\xi_2\eta_2$ differ from $\xi_1\eta_1$ by expressions of the form $a\xi + b\eta + c$, of which the c is the most important part, a and b being small; and thus

$$(X\xi_1\xi_2 + Y\xi_2\eta_1) \text{ differs from } (X\xi_1^2 + Y\xi_1\eta_1)$$

by an expression the important part of which is linear, and thus included in the subsequent linear solution, the small terms being negligible.

17. Further (X, Y) may be regarded either as the coordinates of plate-centre 2 on plate 1, or as the reversed coordinates of plate-centre 1 on plate 2. This is easily seen by the following expressions for the constants a_1 a_2 a_3 b_1 b_2, &c.; which are all expressible in terms of three of them. Let these three be $a_2 = r$, $a_3 = q$, $b_3 = p$, all small quantities (since the axes are nearly coincident), and let us neglect products of p, q, r. Then $a_1^2 = 1 - q^2 - r^2 = 1$ to first order; and since

$$a_1b_1 + a_2b_2 + a_3b_3 = 0 = b_1 + rb_2.$$

and

$$b_1^2 + b_2^2 = 1 - b_3^2 = 1$$

we have

$$(1 + r^2)b_2^2 = 1, \text{ or } b_2 = 1$$

and thus

$$b_1 = -r. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Similarly,

$$c_1 = -q, \quad c_2 = -p \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

so that the scheme of coefficients is

$$\begin{array}{ccc} 1 & r & q \\ -r & 1 & p \\ -q & -p & 1 \end{array}$$

[It is easy to deduce the scheme to the second order, obtaining

$$\begin{array}{lll} 1-\frac{1}{2}(q^2+r^2), & r-\frac{1}{2}pq, & q-\frac{1}{2}pr \\ -r-\frac{1}{2}pq, & 1-\frac{1}{2}(p^2+r^2), & p-\frac{1}{2}qr \\ -q-\frac{1}{2}pr, & -p-\frac{1}{2}qr, & 1-\frac{1}{2}(p^2+q^2) \end{array}$$

but we shall not want more than the first order.]

Thus we have

$$\xi_2 = \frac{\xi_1 + r\eta_1 + q}{1 - q\xi_1 - p\eta_1} \qquad \eta_2 = \frac{\eta_1 - r\xi_1 + p}{1 - q\xi_1 - p\eta_1} \quad . \quad . \qquad (13)$$

and thus we see that if $-q = \mathrm{X}$, $-p = \mathrm{Y}$, the coordinates of centre 2 on plate 1, then to the first order (q, p) or $(-\mathrm{X}, -\mathrm{Y})$ are the coordinates of centre 1 on plate 2, viz. the values of $\xi_2\eta_2$ when $\xi_1 = 0$, $\eta_1 = 0$.

18. The above method of correcting $\xi_2\eta_2$ so that they may be linear functions of $\xi_1\eta_1$ also holds good when these coordinates are not standard coordinates but actual measures, affected with errors of orientation, scale value, refraction aberration, &c. To make the correction in its simplest form, however, it is advisable first to transform one set of coordinates so that they may be *nearly* the same as the other; so that in the small corrections

$$\mathrm{X}x_1x_2 + \mathrm{Y}y_1x_2 \text{ and } \mathrm{X}x_1y_2 + \mathrm{Y}y_1y_2$$

we may put $x_1 = x_2$ and $y_1 = y_2$ and obtain

$$\mathrm{X}x^2 + \mathrm{Y}xy, \qquad \mathrm{X}xy + \mathrm{Y}y^2$$

without sensible error. We need not, however, trouble to eliminate any constant difference between x_1 and x_2 or y_1 and y_2; for if

$$x_1 = x_2 + c \qquad y_1 = y_2 + f$$

with sensible accuracy for substitution in these small terms, then

$$\mathrm{X}x_1x_2 + \mathrm{Y}y_1x_2 = (\mathrm{X}x_2^2 + \mathrm{Y}x_2y_2) + (\mathrm{X}c + \mathrm{Y}f)x_2.$$

and the term $(\mathrm{X}c + \mathrm{Y}f)x_2$ will be absorbed in the linear expression subsequently determined.

19. *Thus to compare measures x_1y_1 on a plate with measures x_2y_2 in nearly the same directions on another plate whose centre has coordinates* XY *on the first; correct x_2y_2 by adding the expressions*

$$\mu^2[\mathrm{X}(x_2+c)^2 + \mathrm{Y}(x_2+c)(y_2+f)], \qquad \mu^2[\mathrm{X}(x_2+c)(y_2+f) + \mathrm{Y}(y_2+f)^2]$$

where c and f are any constants, conveniently chosen so as to make the average corrections small; the corrected $x_2 y_2$ *will then be linear functions of* x_1 *and* y_1, *if there is no optical distortion on either plate. Conversely if after such correction the* $x_2 y_2$ *are found to be linear functions of the* x_1 *and* y_1, *then there is no optical distortion; and any residuals that cannot be satisfied by linear expressions indicate optical distortion.*

20. In dealing with plates taken by an instrument for which we have no direct measures of the position of the centre, *i.e.* of the foot of the normal from centre of object-glass on the plate, we must be prepared for errors in the estimated position of this centre, *i.e.* in X and Y. If we use erroneous values of X and Y, then the residuals will remain affected by expressions of the same form as those considered above, viz.

$$X'x^2 + Y'xy \text{ and } X'xy + Y'y^2$$

where X′ and Y′ are the errors in X and Y. We thus have an obvious test of the correctness of the position of the plate-centre from the measures themselves, distinguishable from other sources of error by the form of these expressions.

21. One convenient practical method of applying these corrections has been indicated in *Monthly Notices*, vol. lv. pp. 108, 109, for the case when X and Y are equal. If $Y = mX$, then

$$Xx^2 + Yxy = X(x + \tfrac{1}{2}my)^2 - \tfrac{1}{4}Xm^2y^2,$$

and when m is 0·5 (or less), the second term may be neglected in the case considered, viz. two plates overlapping one square degree at a corner of each. In any case the second term Xm^2y^2 can be quickly applied as another correction, either by a diagram or a table. The advantage of throwing the expression into this form is that the first term can be applied by a diagram of straight lines, viz. lines parallel to

$$x + \tfrac{1}{2}my = 0.$$

Since $Xx^2 + Yxy = \text{const.}$ represents a hyperbola, it can be represented in the form

$$ax'^2 - by'^2 = \text{const.}$$

in an infinite number of ways (x' and y' being linear functions of x and y), of which

$$X(x + \tfrac{1}{2}my)^2 - \tfrac{1}{4}Xm^2y^2$$

is one; and thus the correction can be applied by a pair of straight-line diagrams in an infinite number of ways. Which of these should be chosen is a matter of practical convenience. The particular form given above seems as convenient as any.

In the present paper these corrections are not applied to the individual stars, but to means of groups only, and no special practical device is necessary.

Comparison of Arequipa and Oxford Plates.

22. We now proceed to the comparison of an Arequipa plate taken with the Bruce photographic doublet with an exposure of 10^m on 1896 August 17, centre at $22^h\ 50^m + 27^\circ{\cdot}5$; with two Oxford plates. The relation of the plates is shown by the diagram (fig. 2).

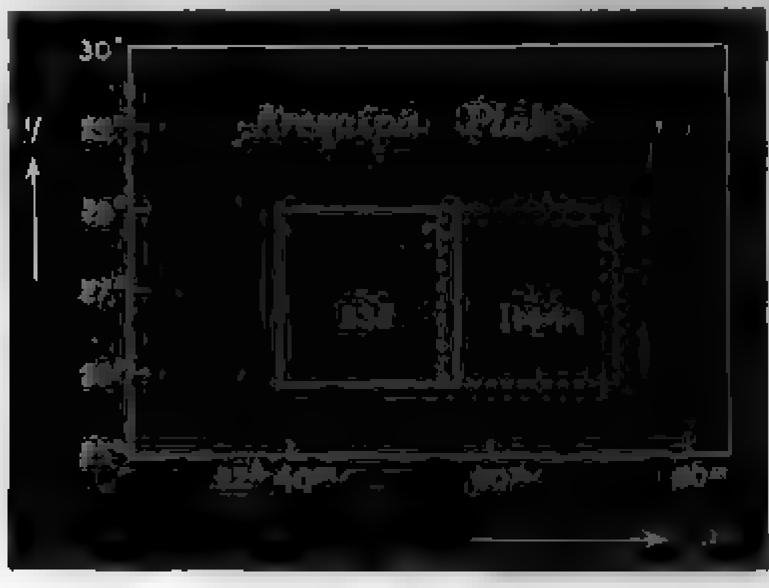


FIG. 2.

23. It was found that the coordinates of the centre of Arequipa plate on plate 1144 are approximately

$$-12{\cdot}3 \text{ and } +7{\cdot}0$$

in *réseau* intervals of twelve to the degree, and hence the coordinates $x_2 y_2$ of the Harvard plate when corrected by ·000001 multiplied by

$$-26x^2 + 15xy \text{ and } -26xy + 15y^2$$

ought to be linear functions of $x_1 y_1$, the measures of the same stars on 1144.

24. Similarly the coordinates of the centre of Arequipa plate on 835 are approximately

$$+9{\cdot}2 \text{ and } +6,$$

and thus the corrections are ·000001 multiplied by

$$+19x^2 + 13xy \text{ and } +19xy + 13y^2$$

25. For comparison of the Arequipa plate with these two Oxford plates, copies were made of the Harvard positive on plates the same size as the Oxford plates, and adjusted to fit as exactly as possible the same region.

Plate 1144 (*A*) *and its corresponding copy* (*B*).

26. A preliminary comparison of measures on A and B showed that it was necessary to apply to the measures of A the corrections

$$+\cdot 173 - \cdot 010x + \cdot 002y \text{ to } x$$

and

$$+\cdot 130 - \cdot 002x \quad \cdot 010y \text{ to } y,$$

in order to get measures near those of B. This was done at once to all the measures of A, so that the corresponding stars were easily identified on B, 291 stars in all. These were divided into groups according to the position on the plate, each coordinate being divided into four, viz.: 0·0 to 6·0, 6·0 to 13·0, 13·0 to 20·0, 20·0 to 26·0

The mean coordinates of the centres of the groups *referred to the centre of plate* 1144 were thus approximately (the unit being 5′ or one *réseau* interval)

$x=$	−10·0	− 3·5	+ 3·5	+10·0	
$y=$	+10·0	+10·0	+10·0	+10·0	
$x=$	−10·0	− 3·5	+ 3·5	+10·0	
$y=$	+ 3·5	+ 3·5	+ 3·5	+ 3·5	
$x=$	−10·0	− 3·5	+ 3·5	+10·0	(J)
$y=$	− 3·5	− 3·5	− 3·5	− 3·5	
$x=$	−10·0	− 3·5	+ 3·5	+10·0	
$y=$	−10·0	−10·0	−10·0	−10·0	

The distances between centres of groups are nearly, though not quite, equal; and as represented in the table, they correspond diagrammatically with their positions on plate 1144; and this arrangement will be adopted for the residuals in what follows without further explanation.

27. The following are the mean residuals for the groups expressed in units of ·0001 of a *réseau* interval or 0″·03, taken in the sense Arequipa minus Oxford.

In x.				In y.				
+ 6	+ 4	+15	+61	+ 4	+10	+ 8	+ 12	
+16	+ 8	+13	+52	+49	+36	+ 7	− 24	
+13	+11	+12	+45	+72	+21	−19	− 76	(K)
+15	+13	+20	+52	+81	+28	−22	−131	

28. From these we first remove any outstanding linear terms. The x residuals require further correction by $-\cdot 00017x$, $-\cdot 0022$, and the y residuals by $+\cdot 00051x - \cdot 00014y - \cdot 0003$. These coefficients are obtained in the following manner :—

Add together the first two columns and subtract the second two: divide by $8\times(10+3\cdot5)=108\cdot0$; the result is the coefficient of x.

Similarly lowest two rows minus highest two rows gives coefficient of y.

Finally mean of all residuals gives the constant term.

This process was uniformly adopted in other similar cases which follow

After applying these corrections the residuals become

In x				In y				
+1	−12	−13	+22	−64	−25	−9	+46	
+11	−8	−15	+13	−10	+10	−17	+19	(L)
+8	−5	−16	+6	+23	+5	+1	−23	
+10	−3	−8	+13	+41	+21	+7	−73	

29. To these we must apply the terms specified in § 23, representing the distance between centres of plates, viz. (omitting a factor ·000001):—

$$\text{To } x,\ -26x^2+15xy, \text{ and to } y,\ -26xy-15y^2$$

[But we may be prepared for an error in the estimated centre of either plate, though the discussion in §§ 3–11 seems to show that the Oxford plates are fairly centred.] In applying such a term as $-26x^2$, which has values $-26, -3, -3, -26$, for the columns of the table, it is well to add the constant $+15$ to all the residuals so as to keep the mean value small. Similarly in applying $-15y^2$ we add the constant -8 to all. The residuals then become

In x				In y				
−25	5	4	−26	31	−9	7	27	
−5	−2	−1	−7	7	+7	−8	+4	M
−2	+9	+0	−10	−8	4	2	−20	
−14	−14	1	−13	−22	+15	+22	−40	

30. It is clear that there is still something systematic about the residuals, which an error of centring will not explain. Thus the y residuals require further correction by a term in xy about as large as that already applied, viz. $-26xy$; but if this is due to an error in the X coordinate of one of the centres, it implies the existence of a correction to the x residuals of $-26x^2$, which would decrease the first and fourth columns compared with the second and third. But the second and third columns are already slightly greater than the other two, and this further correction would upset the x residuals.

31. Let us examine what expressions of the form $Ax^2+Bxy+Cy^2$, and $Dx^2+Exy+Fy^2$ would satisfy the x and y residuals

respectively. The values of x being -10, $-3{\cdot}5$, $+3{\cdot}5$ and $+10$, those of x^2 are 100, 12, 12 and 100; and thus in the x residuals first column + fourth column − (second column + third column) is affected by $4(200-24)A=704A$, whereas the terms Bxy and Cy^2 are eliminated. Similarly the coefficients C, D, and F may be obtained independently of the others.

For the coefficients B and E we must add the four terms in the right-hand top corner to those in the left-hand bottom corner, and subtract the other two corners. The result will be affected by $4(10\times10+10\times3{\cdot}5+10\times3{\cdot}5+3{\cdot}5\times3{\cdot}5)B$, or 729B.

Obtaining the values of the coefficients in this way, we thus deduce the following expressions for correction of the residuals (M):—

$$\text{For } x,\ +\ 3x^2-19xy-2y^2=Ax^2+Bxy+Cy^2,$$
$$\text{For } y,\ +11x^2-23xy-3y^2=Dx^2+Exy+Fy^2,$$

supplying the factor ·000001 throughout. These corrections reduce the residuals to the following:—

In x.				In y.				
−6	−2	−5	+7	−5	−8	−8	+7	
+3	+3	−4	+3	+7	+6	+1	+2	
−2	+6	−5	−2	+6	−11	−3	−6	(N)
−5	+5	+2	+6	+2	+3	+23	−14	

the only noteworthy discrepancy being in the right-hand bottom corner of the y residuals, which is farthest from the centre of the Arequipa plate.

32. If the corrections of the last paragraph were due to imperfect centring we should have A=E, B=F, D=C=0; but these conditions are not fulfilled, and hence we must look for some other cause of error. We may remark that the chief points to be explained are:—

(*a*) The large value of E compared with A.
(*b*) The large value of B compared with F.
(*c*) The sensible value of D.

If there is an error of centring, we must add the same constant to A and E; thus, instead of +2 and −26, their values will be $-2X+2$ and $-2X-26$. If X lies between +1 and −13, A and E are of opposite signs. If $X>+1$, A and E are both negative and $E>A$. If $X<-13$, A and E are both positive and $A>E$. In this last case the X coordinate of the foot of the normal from centre of OG on plate hitherto called the centre, instead of being $-12{\cdot}3$ as in § 23, is −25, or even greater. But an error of twelve *réseau* intervals or more is unlikely, though possible.

33. The meaning of the terms Bxy and Exy, or numerically $-19xy$ and $-23xy$, can be realised on inspection of the residuals

(M). We see that the NE and SW corners (using the analogy of a map) are positive, and the NW and SE are negative. Moreover, this feature is exhibited in a minor degree by every group of four residuals. Take, for instance, the NW group of the x residuals

$$\begin{array}{rr} -25 & -5 \\ +5 & +2 \end{array}$$

and subtract the NW and SE figures from the NE and SW, we get $-5-5+25-2=+13$.

Let the coordinates of these four points be

$$\begin{array}{ll} x,\ y+\beta. & x+\alpha,\ y+\beta. \\ x,\ y & x+\alpha,\ y \end{array}$$

Then if the error at (x, y) be

$$c + ax + by + Ax^2 + Bxy + Cy^2,$$

and we subtract the NW and SE errors from the NE and SW, all the other terms except the Bxy term cut out, and the result is $B\alpha\beta$.

In the case of the group given above, α is 6·5 and β is 6·5; so that $\alpha\beta=42$. For other groups $\alpha\beta$ is $6{\cdot}5\times7{\cdot}0$ or $7{\cdot}0\times7{\cdot}0$—not quite uniform in value but nearly so, and dividing by the proper value of $\alpha\beta$, we may represent the values of B and E in different parts of the plate as follows:—

In x			In y		
−40	−27	33	−36	−33	−57
0	−24	−27	58	2	−31
−17	0	−19	−19	−4	−105

Thus the values of B and E are not quite uniform over the plate: the SW corner seems to be different from the rest.

Theoretical formula for optical distortion.

34. In proceeding to consider optical distortion, we shall (in the first instance at least) consider it a radial displacement, symmetrical round a centre. This centre will probably be near the geometrical centre of the plate, but is not necessarily coincident with it, nor with the foot of the normal from centre of OG on plate. In what follows we shall speak of the geometrical centre of the plate as "the centre", of the foot of the normal from centre of OG on plate, to which we have attached the coordinates (X, Y), as "the normal", and to the centre of optical distortion as the "optical centre." These three points should be coincident for good adjustment of the instrument, but may not be.

35. Since the distortion does not become infinite at the optical centre, an appropriate expression for the displacement along a radius is

$$f(r) = A_0 + A_1 r + A_2 r^2 + A_3 r^3 + \quad . \quad . \quad . \quad . \quad . \quad (14)$$

Clearly $A_0 = 0$; and we may also omit $A_1 r$, which means a simple change of scale. Thus

$$f(r) = A_2 r^2 + A_3 r^3 + \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

The displacement parallel to the axes of x and y are thus

$$f(r) \,.\, x/r \text{ and } f(r) \,.\, y/r,$$

or

$$x\,(A_2 r + A_3 r^2 + \quad . \quad . \quad), \quad y\,(A_2 r + A_3 r^2 + \quad . \quad . \quad),$$

representative terms being

$$\mu x r^n \text{ and } \mu y r^n$$

where n is some positive integer. Now consider the displacement in x, say $\varphi\,(x, y)$. In the neighbourhood of a point (ξ, η) let the coordinates of a point be $(\xi + x, \eta + y)$.

Then

$$\phi(\xi + x, \eta + y) = \phi\,(\xi, \eta) + x\phi_\xi + y\phi_\eta$$
$$+ \tfrac{1}{2}\,(x^2\phi_{\xi\xi} + 2xy\phi_{\xi\eta} + y^2\phi_{\eta\eta})$$
$$+ \text{ higher powers of } x \text{ and } y.$$

But by our method of dealing with the plate we have eliminated the linear terms

$$\varphi + x\phi_\xi + y\phi_\eta$$

whatever they may be. Further, we have found by experiment an expression of the second order, which approximately satisfies the residuals, and this must be identical with the expression

$$\tfrac{1}{2}\,(x^2\phi_{\xi\xi} + 2xy\phi_{\xi\eta} + y^2\phi_{\eta\eta})$$

so far as it goes. For the point (ξ, η) we take the centre of plate 1144, and for (x, y) the coordinates of a star referred to this centre. Now

$$\frac{d}{dx}(xr^n) = r^n + nx^2 \,.\, r^{n-2}, \quad \frac{d}{dy}(xr^n) = nxyr^{n-2}$$

$$\frac{d^2}{dx^2}(r^n x) = nxr^{n-4}[3r^2 + (n-2)x^2], \quad \frac{d^2}{dxdy}(r^n x) = nyr^{n-4}[r^2 + (n-2)x^2]\,.$$

36. Hence, if we attempted to represent the displacements

in x and y in the neighbourhood of a point whose coordinates are $(\xi\eta)$ by expressions of the form

$$Ax^2 + Bxy + Cy^2$$
$$Dx^2 + Exy + Fy^2,$$

we should find

$$\begin{aligned} A &= 3\xi \,.\, \mu n \rho^{n-4}[\rho^2 + \tfrac{1}{3}(n-2)\xi^2] & D &= \eta \,.\, \mu n \rho^{n-4}[\rho^2 + (n-2)\xi^2] \\ B &= 2\eta \,.\, \mu n \rho^{n-4}[\rho^2 + (n-2)\xi^2] & E &= 2\xi \,.\, \mu n \rho^{n-4}[\rho^2 + (n-2)\eta^2] \\ C &= \xi \,.\, \mu n \rho^{n-4}[\rho^2 + (n-2)\eta^2] & F &= 3\eta \,.\, \mu n \rho^{n-4}[\rho^2 + \tfrac{1}{3}(n-2)\eta^2]. \end{aligned}$$

Thus whatever be the value of n we have

$$B = 2D, \; E = 2C.$$

If $n=2$, the coefficients have the values

$$\begin{array}{lll} A = 3k\xi & B = 2l\eta & C = k\xi \\ D = l\eta & E = 2k\xi & F = 3l\eta \end{array}$$

and unless n is very large the *ratios* of the coefficients are not very different from these.

37. Whatever be the value of n, if it is not less than 2 we have A E C all of the same sign, and D B F of the same sign. Further

$$A - E = \xi\mu n\rho^{n-4}[\rho^2 + (n-2)(\xi^2 - 2\eta^2)]$$
$$A - C = \xi\mu n\rho^{n-4}[2\rho^2 + (n-2)(\xi^2 - \eta^2)].$$

Thus A is always numerically greater than C and generally greater than E or 2C. Similarly F is generally numerically greater than B, and always than D.

These relations are of the greatest use in determining whether any given systematic errors are due to optical distortion of any kind.

38. We have made no assumption as to the position of the optical centre, and hence it may be anywhere; or there may be several optical centres, each with its own kind of distortion; and the images may suffer a complex displacement which is the resultant of these different distortions. Still this criterion holds: viz. that if over any region we express the displacements in x and y by terms of the second order, then whenever there is a term $2Pxy$ affecting the x residuals there must be terms $(Rx^2 + Py^2)$ affecting the Y residuals, where R is at least as great as P and probably twice or three times as great, and is of the same sign.

39. Such a fundamental relationship must have a geometrical meaning, and on examining a simple case the meaning is seen to be as follows :—

Let a square A B C D (fig. 3) be so distorted that the displacements of all points in the x direction are represented by an expression $+ B x y$, the displacement in the y direction being for

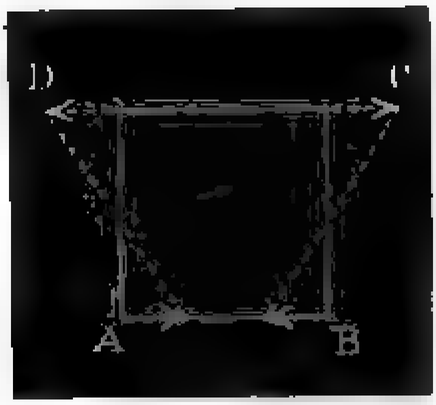


Fig. 3.

the moment not specified. Let the coordinates of the corners be

$$A(-1, -1),\ B(+1, -1),\ C(+1, +1),\ D(-1, +1),$$

so that the displacements of A and C are positive and of B and D negative. The square takes the shape shown in fig. 4.

40. Now let us consider any displacement of points P Q R S by radiation from a centre O, which displaces P Q R S to $p\,q\,r\,s$ (fig. 5). We assume O to lie on the line midway between P Q and R S.

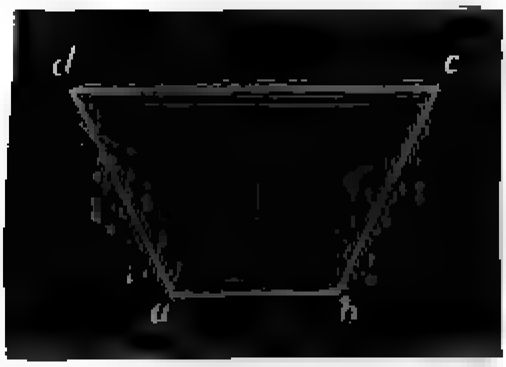


Fig. 4.

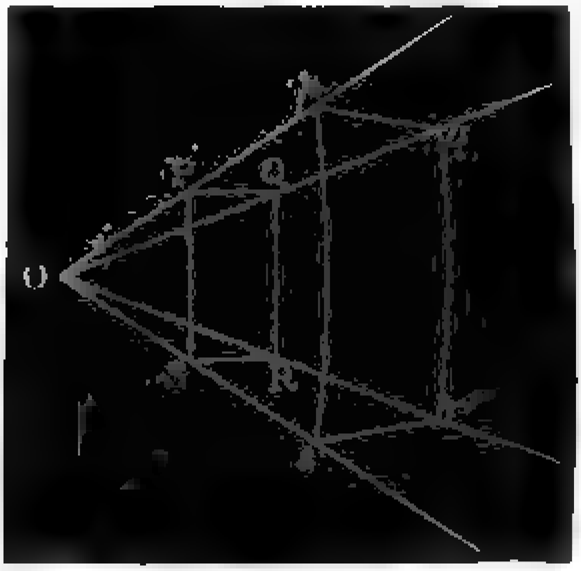


Fig. 5

Then the lines joining $p\,s$, $q\,r$ will be parallel to P S, Q R; but $p\,q$, $r\,s$ will not in general be parallel to P Q, R S. For if they were then the ratio O p : O P would be equal to the ratio O q : O Q, which represents a simple change of scale of the whole figure This case is excluded from consideration as involving no distortion; and such change of scale, in either direction, as accom-

panies distortion, is allowed for analytically by linear expressions. Thus we must suppose $q\,r$ either greater or less than $p\,s$. Let it be less as in the figure. Then this means that the ratio O p, O P (in which radii through O are increased) decreases with distance from O, and hence points on P S between P and S, being nearer O, will be displaced proportionately further from O than P and S; *i.e.* the line P S will be concave to O, and so will $q\,r$.

Hence when we have a pair of sides P Q, R S suffering rotation in opposite directions to $p\,q$, $r\,s$, the other sides P S, Q R become curved.

41. Now returning to figure 3, the sides A D, B C suffer rotation in opposite directions to $a\,d$, $b\,c$ through the term $+\,Bxy$ in the x coordinate. Hence the sides D C and A B will be curved, which implies a term depending on x^2 in the y coordinate. In this way we can trace the geometrical meaning of the analytical criterion obtained above; though the criterion is perhaps simpler in its analytical form.

42. Returning now to § 31, if we are to explain the values of A B C D E F there given, viz. $+3, -19, -2, +11, -23, -3$, by optical distortion of the kind above considered, then we notice that since $C = -2$, $E = 2\,C$ (accurately), and $A = 3\,C$ (approximately), must be small. The value -2 for C is not necessarily exact, but if we make E and A large we shall introduce a troublesome term in C. We have thus to satisfy as best we can the conditions

$$-2X + 3 = A = 3C, \quad 2X - 23 = E = 2C, \quad C = -2.$$

Solving the equations

$$2X + 3C = 3, \quad 2X + 2C = -23, \quad C = -2$$

by least squares we get $C = +7$, $X = -14$.

43. Similarly solving

$$2Y + 3D = -3, \quad 2Y + 2D = -19, \quad D = +11$$

by least squares we get $D = +13$, $Y = -21$; and the theoretical expressions representing optical distortion and error of normal are

$$m\,x = -7x^2 - 16xy + 7y^2,$$
$$m\,y = +13x^2 - 14xy - 3y^2.$$

Comparing these with the expressions deduced from the residuals in § 30, viz.

$$+3x^2 - 19xy - 2y^2$$
$$+11x^2 - 23xy - 3y^2$$

the differences (observed − calculated) are

$$+10x^2 - 3xy - 9y^2$$
$$-2x^2 - 9xy + 0y^2,$$

so that even with the assumption of a considerable error of centring (X = − 14, Y = − 21) in one or other of the plates compared, and the best value we can get of the optical distortion coefficients, we cannot satisfactorily explain the residuals. The conviction begins to form that the residuals M of § 29 are *not* due to optical distortion, but to some other source of error.

44. But before dismissing entirely the idea of optical distortion let us take another plate, and see whether the suggestions of this plate are borne out by measures in a different part of the Arequipa plate. The suggestions are practically the following :—

(1) That the "normal" is not at the centre of one of the plates, but at a point differing X and Y by (− 14, − 21). The normal is thus at a distance of nearly $2\frac{1}{2}°$ from the "centre" of the plate—a rather extravagant supposition.

(2) There is optical distortion about an optical centre lying in the left-hand bottom corner of plate 1144, the coordinates of the optical centre with reference to the centre of plate 1144 being (− $2p$, − $3p$), where p is not yet determined.

The numerical expressions representing the average optical distortion over the plate are

$$+21x^2+22xy+\ \ 7y^2 \text{ in } x,$$
$$+11x^2+14xy+33y^2 \text{ in } y.$$

We thus proceed to the examination of plate 835.

Plate 835 (*Oxford*) *and its corresponding Copy* (*Arequipa*).

45. A preliminary comparison of measures on the plate showed that it was necessary to apply to the measures of 835 the corrections

$$-\cdot010\,x \quad +\cdot003y \qquad \text{to } x$$
$$-\cdot003\,x \quad +\cdot010y+\cdot015 \text{ to } y$$

in order to get measures near those of Arequipa plate. This having been done, groups were formed just as in the case of plate 1144 (see § 26), and the following mean residuals found, the unit being, as before, ·0001 of a *réseau* interval, or 0″·03 :—

In x.				In y.				
(+105)	+15	+16	−2	(−15)	−34	−43	−54	
+39	+32	+13	−4	+19	+2	+9	+16	(P)
+46	+55	+31	+8	+50	+53	+57	+78	
+31	+70	+71	+53	+37	+76	+96	+117	

The group bracketed depends on two stars only, and the x residuals seem exceptional. In deducing the following constants the number for x has been taken as +55, instead of +105.

46. From these we remove linear terms. The x residuals require further correction by

$$+\cdot 00014x + \cdot 00019y - \cdot 0033,$$

and the y by

$$-\cdot 00008x + \cdot 00062y - \cdot 0029,$$

and the results are :—

In x.				In y.				
(+77)	− 4	+ 7	− 2	+ 26	+ 2	− 13	+ 29	
− 1	+ 1	− 8	− 16	+ 20	− 2	− 1	+ 1	(Q)
− 8	+ 10	− 4	− 18	+ 7	+ 5	+ 3	+ 19	
− 35	+ 13	+ 24	− 15	− 46	− 12	+ 2	+ 18	

47. To these we must apply terms for difference of normals of the plates. In the first instance, we shall assume the normal coincident with the centre, as in § 24, and apply the corrections

$$+19x^2 + 13xy \text{ and } +19xy + 13y^2,$$

giving results as follows :—

In x.				In y.				
(72)	18	+ 3	+ 19	+ 13	+ 1	0	− 4	
+ 2	8	− 15	− 3	+ 7	10	− 5	+ 2	(R)
+ 5	3	− 15	− 15	+ 8	+ 1	− 5	+ 6	
− 14	− 9	+ 10	+ 10	− 21	+ 1	+ 1	+ 5	

48. If we represent these by expressions of the form $Ax^2 + Bxy + Cy^2$, $Dx^2 + Exy + Fy^2$, we get for the values of the coefficients

$$-8x^2 - 3xy - 12y^2$$

and

$$+5x^2 + 4xy + 1y^2.$$

These are small, as may be expected from inspection of the residuals (R).

49. If the normal is not coincident with the centre of the Harvard plate, and the error is as indicated by plate 1144, see §§ 43, 44, so that we should correct residuals (R) by

$$-28x^2 - 42xy \quad -28xy - 42y^2,$$

then the residuals will require additional correction by

$$+20x^2 + 39xy - 12y^2$$
$$5x^2 + 32xy + 43y^2,$$

but in these expressions the relations A=3C, E=2C, B=2D, F=3D are not even approximately fulfilled.

If there is an error of normal in the case of this plate it would seem to be in the contrary direction to that of the other plate, at least in the X coordinate, seeing that C = −12, and hence A and E should be also negative so far as optical distortion is concerned. Though D is negative (= −5), it is small; and we cannot say anything certainly about the sign of B and F, but they should not be large.

Now the error of normal is the combined error of normal in Arequipa and Oxford plates; and though the Arequipa error is the same in both cases, the Oxford plates may have different errors. But even with this freedom of action it was found, on trial, impossible to make any satisfactory compromise which would explain the systematic errors given above on the hypotheses of error of normals and of optical distortion only.

50. I was thus led to examine other possible sources of error. The explanation of the residuals was ultimately found, as I believe, in the curvature of the Arequipa plate, and consequent errors in copying, as will be explained presently.

The following possible sources of error which were considered and found insufficient to explain the residuals may be briefly mentioned:—

51. *Inaccurate Estimation of Centres of Groups.*—In §§ 26–29 it is mentioned that after the application of the main corrections to the individual star places, subsequent corrections were only applied to the mean residuals of groups; and, further, that in so applying them the mean coordinate of a group extending from 0·0 to 5·9 in x and 13·0 to 20·0 in y was assumed to have coordinates 3·0 and 16·5 respectively. To see whether this summary procedure had affected the residuals the actual mean coordinates of the groups on plate 1144 (which is the more difficult to explain) were formed, and were found to differ from the assumed means (viz. 3·0, 9·5, 16·5, 23·0 in each coordinate) as follows:—

In x.				In y.				
−0·4	−0·5	−0·1	−0·5	+0·3	−0·6	−0·2	−0·2	
−0·1	−0·8	+0·1	+0·2	−0·2	+0·3	+0·2	−0·8	(S)
+0·1	+0·4	+0·5	−0·1	−0·8	−0·9	+0·3	−0·4	
0·0	+1·1	+0·2	+0·2	0·0	+0·2	+0·8	−0·1	

52. In § 28 it is stated that the means of groups were corrected, in the first instance, by the quantities $-{\cdot}00017x - {\cdot}0022$ and $+{\cdot}00051x + {\cdot}00014y - {\cdot}0003$. Now, it is clear that the use of approximate values for x and y differing from the true values by quantities such as those in table (S) could not produce errors such as those we have to explain. The largest error in the x coordinate of a group is +1·1, which is to be multiplied by ·00051, giving +·0006, while we are concerned with quantities four or five times as large as this.

53. Under the same head may be mentioned the application of a term such as Ax^2 to the middle of a group extending (say) from $(x-y)$ to $(x+y)$. We have applied Ax^2, whereas the proper correction is

$$\frac{1}{2y}\int_{x-y}^{x+y} Ax^2dx = \frac{A}{6y}\left[(x+y)^3-(x-y)^3\right] = Ax^2 + \frac{1}{3}Ay^2$$

The error thus made is $\frac{1}{3}Ay^2$; but if the groups are equal in width this is a constant, and only increases all the residuals equally; and since we have subtracted a constant so as to keep the mean residual zero, we may neglect this correction entirely. The groups are not precisely equal in width, the two inner ones extending over seven *réseau* intervals and the outer ones over six, but the error made is very small.

It may be remarked that a term Bxy can be applied to the mid-point of a group without any error.

54. *Refraction.*—The Arequipa plate was taken at some distance from the zenith, and it becomes necessary to examine the refraction correction, which may involve higher powers of the coordinates than the first. A simple method of calculating the differential refraction has been given in *Monthly Notices*, lvii. p. 133 &c., where it is shown that if (X, Y) be the coordinates of the zenith on the plate, μ the coefficient of refraction, then the refractions in x and y are

$$\Delta x = (x-X)t, \quad \Delta y = (y-Y)t \text{ *}$$

where

$$t = -\mu(1+x^2+y^2)(1+Xx+Yy)^{-1}$$

so that to the second power of x and y

$$\frac{\Delta x}{\mu} = X - x(1+X^2) - yXY$$
$$+ x^2X(2+X^2) + xyY(1+2X^2) + y^2X(1+Y^2).$$

The first term X represents the refraction at the centre of the plate, the terms $x(1+X^2)$ and yXY are included in the general linear terms $ax+by$. It is with the terms of the second order that we are concerned.

55. To calculate X and Y we have

$$\tan q = \tan\lambda \cos(S-A)$$
$$X = \tan(S-A)\sin q \sec(P-q) \quad Y = \tan(P-q)$$

where

A = 22ʰ 47½ᵐ the R.A. of plate centre.

P = 62°·5 the N.P.D. of plate centre.

S = 21ʰ 36ᵐ the sid. time of exposure.

λ = 106° 24′ colatitude of Arequipa.

* There is a mistake of sign in line 19 of p. 136, but the following line is correct: See also p. 135, line 12.

56. It is clear without any actual calculation that $Y = -\tan 45° = -1$ nearly; and $X = -0{\cdot}4$ roughly. Thus the terms of the second order are about

$$\text{in } x \quad -\mu[0{\cdot}9\,x^2 + 1{\cdot}3\,xy + 0{\cdot}8y^2]$$
$$\text{in } y \quad -\mu[3{\cdot}0\,x^2 + 1{\cdot}2\,xy + 1{\cdot}2\,y^2]$$

where x and y are expressed in circular measure, and μ is the coefficient of refraction $= 0{\cdot}2$ of a *réseau* interval. Thus, if $x = 1° = 0{\cdot}017$, $y = 0{\cdot}017$, the largest value of the correction to y in *réseau* intervals is

$$0{\cdot}2 \times 5{\cdot}8 \times ({\cdot}017)^2 = {\cdot}0003,$$

and the correction to x is smaller still.

Thus in the present discussion these corrections are too small to have any sensible influence and may be neglected.

57. This does not mean that the correction for refraction to the second order of x and y can be neglected *over the whole Arequipa plate*; for in the corners of this plate we may have $x = 0{\cdot}05$, $y = 0{\cdot}04$; and thus the correction in y at a corner may be

$$0{\cdot}2 \times ({\cdot}0075 + {\cdot}0024 + {\cdot}0019) = 0{\cdot}0236.$$

a considerable quantity. When, however, we are dealing with a portion only of this large plate, two degrees square, these corrections can be replaced by linear corrections, which are nearly equivalent.

58. *Size of Star Discs.*—No account has been hitherto taken of the magnitudes of the stars. When photographic star discs become at all elongated, there is often a denser nucleus near one end; and the question arises what to measure, whether the centre of the ellipse or the nucleus. Since the dense nucleus is the first portion of the image to appear on the plate, and thus for faint stars the only portion to appear, it is the best point to measure if we want results consistent between bright and faint stars. But in the brightest stars the nucleus disappears, the whole image being equally dense. Hence there is something of a dilemma in measuring elongated stars, of which there are many examples both on Arequipa and Oxford plates; and in the case of unequal distribution of bright stars on a plate, we may get systematic errors. A glance at plate 1144 showed that the brighter stars nearly all lay near one diagonal; and this seemed to afford a possible clue to the discrepancies under consideration. Accordingly the groups were divided into bright and faint stars and the means compared; but it was soon seen that, though there were unmistakable differences, the effect of such differences was far too small to explain our discrepancies. If the bright stars were omitted near the one diagonal and retained in other places, very little alteration was made in the means.

Curvature of the Plate.

59. While considering all possible sources of these systematic errors, my attention was called by Mr. Bellamy to the fact that the Arequipa photograph was not on plate glass, and I was led to examine its curvature by putting the edges downwards on a piece of paper and running a pencil along them; then turning the paper through 180° and again ruling along the edge with a pencil. In this way the plate was found to have a considerable curvature in opposite senses for the two pairs of parallel edges. In the E. and W. direction the film is concave; in the N. and S. direction, convex. The depth of the middle of an edge below the ends was in the case of the long south edge as much as 2^{mm} or 3^{mm}; and in all cases a considerable fraction of 1^{mm}. On bending the plate with the hand, it was found that the greatest curvature could be easily doubled or reduced to zero. Mr. Bellamy remembered that in making the copies on 6 in. × 6 in. plates, he had used a certain amount of pressure. The smaller plate AB (see fig. 6) was placed film downwards on the Arequipa plate

Fig. 6

CD (film up), then cloth placed at the back of AB, and then a board, KL, on the cloth. Pressure was then applied by Mr. Bellamy's two hands at the points indicated by the arrows. If this pressure had any effect on the curvature of CD it would tend to increase the concavity of the film, which is already concave in the direction CD.

60. Thus we may take it that the Arequipa plate was probably considerably curved when the copy was being made, and it is unlikely that the film of the plate which received the copy was everywhere in contact with the other. Since glass will bend so as to take up the amount of curvature now under consideration, complete contact might have been secured perhaps if special attention had been paid to the point; but it was not, and thus the two films may have had a space between them, as shown in fig. 7.

61. If now the rays of light with which the film of CD was illuminated in order to make the copy were strictly normal to the plate AB, then the image of any point O would fall at *m*.

If, however, the light fell obliquely at an angle θ with the normal, the image of O would fall at l or n, showing a displacement $Om \times \tan\theta$ with reference to the former position, while stars at A and B would remain undisplaced. It is not an extravagant supposition to put $\theta = 6°$, even if some care is exercised in holding the plate normal to the incident light; so that $\tan\theta = 0{\cdot}1$ say. And thus for a displacement of the image such as is in question, amounting to 0·003 of a *réseau* interval or 0·015 of a mm., we only require a separation of the films by

FIG. 7.

$0^{mm}{\cdot}15$, which is quite likely to have occurred in the copying. If we may allow a greater obliquity than 5° for the incident light, a less separation of the films will account for residual errors such as are to be explained.

62. Let z denote the separation of the films at any point (x, y). Then over any limited area we may put

$$z = e + ax + by + \alpha x^2 + \beta xy + \gamma y^2.$$

If the light is in parallel rays, making $\angle\theta$ with the axis of z, the displacement of the image at xy is in a fixed direction and $= z\tan\theta$. Thus the displacements in x and y are uz and vz, when u and v are constants; and are thus proportional. This affords a simple criterion for judging of this kind of error, viz.

The error in x bears a constant ratio to the error in y.

63. If we have eliminated the linear terms, and are left as before with displacements

$$Ax^2 + Bxy + Cy^2 \text{ in } x \text{ and } Dx^2 + Exy + Fy^2 \text{ in } y,$$

then this criterion gives

$$\frac{A}{D} = \frac{B}{E} = \frac{C}{F}.$$

64. Recurring to § 31, we see at once that this explanation will suit the expressions there given very closely, if we allow for small errors in the coefficients. We there found that after correcting the Arequipa plate for difference of centre from 1144, and for linear terms, the residuals were expressible with some accuracy by

$$+3x^2 - 19xy - 2y^2 \text{ in } x$$
$$+11x^2 - 23xy - 3y^2 \text{ in } y.$$

Taking 1·2 as the ratio of E to B, and deducing the values of A and C from those of D and F, we should get for A, B, C

$$+9, \quad -19, \text{ and } -3,$$

as compared with

$$+3, \quad -19, \text{ and } -2$$

65. If we allow for possible error of tilt of the plates we could, of course, satisfy the relations $\frac{A}{D}=\frac{B}{E}=\frac{C}{F}$ exactly, for we have two disposable constants, X and Y, with which to satisfy the equations, which now become

$$\frac{+3+X}{11}=\frac{-19+Y}{-23+X}=\frac{-2}{-3+Y}.$$

Thus we have

$$Y=19+(X-23)(X+3)/11=3-22/(X+3),$$

which leads to the cubic in X,

$$(X+3)^2(X-23)+176(X+3)+242=0,$$

which has a real root between -4 and -5, giving $Y=+22$ or $+24$. The actual errors of centring expressed in *réseau* intervals are half these quantities, owing to the factor $\mu^2=\cdot 00000211$ which occurs in such work (see § 19); and these are quite possible errors of centring, the errors due simply to curvature being expressed by (say)

$$-x^2+3xy-2y^2$$
$$+11x^2-19xy+19y^2$$

But this is treating these expressions rather too seriously.

66. As regards the other plate, No. 835, the residual expressions given in § 48 are

$$-8x^2-3xy-12y^2$$
$$-5x^2+4xy+1y^2$$

The ratios A/D, B/E, C/F are not equal, but the quantities A, B, C, D, E, F are all small. If we allow for an error of centring as above, putting

$$\frac{X-8}{-5}=\frac{Y-3}{X+4}=\frac{-12}{Y+1},$$

we get

$$Y=3-(X+4)(X-8)/5=\quad 1+60/(X-8).$$

Thus,

$$+(X+4)(X+8)^2-20(X+8)+300=0,$$

or

$$X=-7; \ Y=3-9=-6,$$

and the errors due to curvature are

$$-15x^2 - 9xy - 12y^2 \text{ in } x$$

and

$$-5x^2 - 3xy - 5y^2 \text{ in } y.$$

67. The errors in X and Y and the expressions due to curvature of plate do not accord very well with those of the other plate; but there is, after all, no reason why they should. The curvature which the plates concerned had at the time of copying depends on the particular strain to which they were subjected at the time; and as regards errors of centring three plates are involved, exposed under unknown conditions.

68. Further, there is no great necessity for conformity in these expressions all over either plate. Thus local differences, as remarked in § 33, are quite accordant with the present explanation.

69. To sum up, there is no difficulty in accounting for the residual differences between the Oxford plates and the Arequipa plate in this way. They can be accounted for both in character and magnitude. In ignorance of the precise conditions under which these copies were made it is useless to examine more in detail whether the exact shape of the particular plates concerned can be traced in the errors. If the present explanation of the errors is correct, and the curvatures of the plates at the time of exposure, as well as the exact direction of incident light, were known, we ought to be able to establish the causation completely, and this may possibly be done in future experiments. But this opens up a new line of investigation, and must be deferred to a future paper.

Conclusions.

70. The conclusions of the present paper may be thus stated:

(*a*) The Oxford astrographic catalogue plates of 130′ × 130′ show no systematic errors larger than 0″ 15, which can be attributed to optical distortion.

(*b*) A plate taken at Arequipa with a photographic doublet shows no sensible optical distortion over an area covered by two Oxford plates placed side by side, and thus presumably over an area of 4° × 4° at least.

(*c*) Certain systematic differences which were found on comparing the Arequipa plate with Oxford plates are not due to optical distortion but to curvature of the plates used in making photographic copies; to the want of complete contact; and to obliqueness in the illumination.

(*d*) A simple criterion for the existence of any kind of optical distortion which consists in a radial displacement of stars from a centre, or in the composition of any number of

such displacements, is arrived at in the paper and illustrated.

(e) A simple criterion is also given for detecting errors in star measures due to curvature of a plate, which is copied on to another without being completely in contact with it, under oblique illumination.

On the Errors of Star Photographs due to optical Distortion of the Object-glass with which the Photograph is taken. Second paper. By H. H. Turner, M.A., F.R.S., Savilian Professor.

1. In a previous paper on this subject I gave the comparison of two Astrographic Catalogue plates taken at Oxford with corresponding portions of a large plate taken at Arequipa, Peru, with a photographic doublet. In each case the coordinates of some 250 stars on the two plates were compared, and the algebraical relations between them were found to be expressible with sensible accuracy by the formulæ

$$x' = c + ax + by + Ax^2 + Bxy + Cy^2$$
$$y' = f + dx + ey + Dx^2 + Exy + Fy^2$$

The linear terms $c + ax + by$ and $f + dx + ey$ were not further considered ; but it was pointed out that the values of the coefficients A B C D E F were inconsistent with the idea that these terms were due to optical distortion of the object-glass, if the corresponding displacement of a star image was along the radius from some centre, and a function of the distance from the centre. It was shown to be probable that these terms represented errors of copying the Arequipa plate under oblique illumination ; and it was inferred that the optical distortion over a field of at least $4° \times 4°$ was small.

2. In the present paper additional evidence is given of the existence of errors of copying. Measures of a third region still further from the centre of the Arequipa plate are examined in the terms of the second order, which still show no evidence of sensible optical distortion. Finally, the linear terms $c + ax + by$ and $f + dx + ey$, hitherto neglected, are considered ; again without finding evidence of optical distortion.

Errors of Copying.

3. In the previous paper no direct evidence was given that the errors were due to copying ; but this was shown to be a probable explanation of the discrepancies It was found that the glass of the Arequipa positive was sensibly curved ; and it was supposed that in copying a portion of it on another plate the

films were not in complete contact owing to this curvature. Hence, if the illumination used for copying were slightly oblique, the star images in different parts of the plate would be relatively displaced. Thus, in fig. 1, if A S B be one (curved) film, A M N B the other, in contact with the former at A and B, but not at S; then if the illumination be in the direction S M, the star image S appears at M; if in the direction S N, at N; while the stars at A and B are the same in both cases.

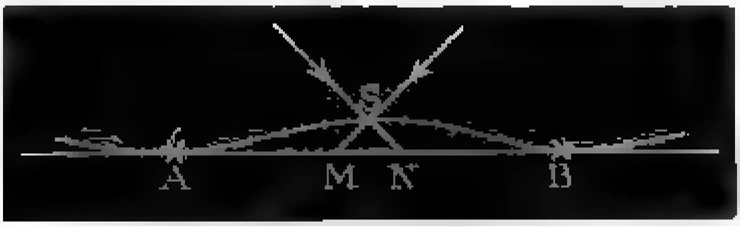


Fig. 1

4. To test this hypothesis a portion of the Arequipa plate was copied twice on the same plate under illuminations differing considerably in direction, and the distances between the pairs of images measured. The plate was held in the first instance so that light from a gas jet fell at an angle of $+45°$ with the normal, in the plane through the axis of x; then after a small displacement it was again exposed, with the light making an angle of $-45°$. It will be remarked that here we are not concerned with the performance of the Bruce doublet in any way. The stars are merely arbitrary points on the plate copied twice over, and the only differences allowable are of the form

$$by + c \text{ in } x \text{ and } -bx + f \text{ in } y$$

representing an arbitrary displacement and rotation in moving the plate slightly, so that the second exposure should not fall on the first. The mean differences of groups in x and y corrected by expressions of the above form were as below, in the notation of the previous paper, the unit being ·0001 of a *réseau* interval, or 0″·03.

In x				In y			
−5	+3	+17	−9	−21	−14	−8	−7
−14	+7	+36	+7	−13	−9	−6	−2
−13	+7	+24	+6	−19	−9	0	+8
−10	−7	+17	+8	−18	−5	−1	+12

5. In the same way as in the former paper we find that algebraical expressions representing these are:

$$\text{for } x, \text{ const} + \cdot00013x + \cdot00001y - \cdot000001(19x^2 + 2xy + 6y^2)$$
$$\text{for } y, \text{ const.} + \cdot00010x - \cdot00004y - \cdot000001(1x^2 + 5xy + 2y^2)$$

These expressions reduce the above differences to the following:

In x				In y			
+12	5	+4	−14	−3	0	+2	+1
−1	5	+16	4	+3	+2	−3	−2
+2	−5	+4	7	−1	0	+1	+2
+13	−11	+3	+1	+2	+5	−3	+2

6. If the differences are due to errors of the kind suggested, then both the algebraical expressions and the residuals in x and y should be in a constant ratio. Looking first at the residuals, take the five largest residuals in x, and write under them the corresponding residuals in y.

$$\begin{array}{lrrrrr} x & +16 & +12 & -14 & +13 & -11 \\ y & -3 & -3 & +1 & +2 & +5 \end{array}$$

The ratio of the y residuals to the x residuals is thus small, its mean value being $-10:66$; and there is a reason for this, the obliquity of illumination being changed principally in the direction of the x axis, though the position of the plate being only roughly estimated, there was probably a slight change of direction in the other coordinate also. Thus corresponding to the term $-19x^2$ for x, we should expect a term $+3x^2$ in y, whereas we find $-1x^2$; but this need not trouble us, for coefficients smaller than 10 in these terms may be regarded as largely accidental.

In considering the terms of the first order, it must be remembered that we have an unknown rotation of one exposure with reference to the other; thus, instead of

$$13x+1y \text{ and } 10x-4y$$

we should write

$$13x+(1+b)y \text{ and } (10-b)x-4y.$$

Putting $b=13$ we get

$$13x+14y \text{ and } -3x-4y,$$

which are approximately in the ratio of 66 to -10. So that there is no theoretical difficulty in getting this accordance between these terms and the residuals. But this is treating too seriously terms of the magnitude of $-3x-4y$, which may be in error by several units. It is probably better to put $b=5$ and get

$$+13x+6y \text{ for } x, \text{ and } 5x-4y \text{ for } y,$$

of which we can regard as largely accidental the smaller terms, *i.e.* all except the $+13x$.

Hence, the main part of the discrepancy between exposures is represented by

$$\text{Const.} + \cdot000130\, x - \cdot000019\, x^2 \text{ in } x$$

and

$$\text{Zero} \qquad \text{in } y$$

neglecting small terms as largely accidental.

This can be put into the form

$$\text{Const.} - \cdot000019\, (x - 3\cdot4)^2$$

and thus $x = 3\cdot4$ is the point, either of closest contact between the two films in copying, or of greatest separation. Since it is more likely that the edges of the superimposed plate were in contact with the film to be copied, with a gap in the middle, rather than that the contact was in the middle with separation at the edges, $x = 3\cdot4$ is probably the point of greatest separation. But this is not material.

7. What *is* rather important is the numerical smallness of the quantity. The obliquity of illumination was purposely exaggerated, and we should have expected at least five times the sort of quantities which were to be explained in the last paper, such as

$$+ 11x^2 - 23xy - 3y^2$$

(see p. 451); whereas, the quantity obtained is only about the same size. This is capable of explanation in more than one way, thus:—

(*a*) The plates may have been pressed closer together on the present occasion.

(*b*) The errors dealt with in the last paper may not be wholly due to the copying at Oxford, but partly to the process of copying the original negative at Arequipa.

8. In any case the existence of errors of this kind is fairly well established, and we may now return to the main object of the investigation, the possible existence of optical distortion. The next step was to take a copy of a portion of the Arequipa plate still further from the centre: to compare it with the corresponding Oxford plate as before: to express the residuals, after clearing away linear terms, by expressions of the second order, and to see whether at this greater distance from the centre these were becoming larger than could be explained by errors of copying.

9. The centres of the two plates previously considered occupied the following positions on the Arequipa plate,

No.	x	y	r
1144	+12	−7	14
835	−9	−6	11

The new plate taken was with centre,

207 -25 $+6$ 26

To the Oxford measures were applied the corrections,

$$+\cdot220 - \cdot010x - \cdot004y \text{ to } x$$
$$0 \quad + \cdot004x - \cdot010y \text{ to } y$$

and it was then compared with the corresponding portion of the Arequipa plate. The mean differences were as below, the unit being $0''\cdot03$.

In x				In y			
+22	+165	+289	+368	+274	+177	+70	+9
+39	+151	+304	+368	+183	+116	+23	−40
−14	+116	+262	+311	+109	+59	−5	−35
−10	+96	+209	+282	+37	+11	−13	−37

10. When corrected by the linear expressions

$$-\cdot0185 - \cdot00169\,x - \cdot00042y \text{ in } x,$$

and

$$-\cdot0059 + \cdot00092\,x - \cdot00064y \text{ in } y,$$

these become

In x				In y			
−36	−3	3	−28	+59	+22	−21	−22
+8	10	+45	−1	+10	+3	−26	−29
−15	+5	+33	−28	−20	−10	−10	+20
16	12	+7	−30	−50	−16	+24	+60

11. Calculating for these corrections of the second order as in the previous paper, we find

$$(-32x^2 - 10xy + 16y^2) \times \cdot000001$$
$$(-9x^2 + 54xy - 17y^2) \times \cdot000001$$

Now the centre being at $(-25, -6)$, or the coordinates of the centre of the Arequipa plate on this plate being $(+25, -6)$, the theoretical corrections for difference of normals

$$\mu^2 (Xx^2 + Yxy) \text{ and } \mu^2 (Xxy + Yy^2)$$

(where μ is the circular measure of the *réseau* interval or $\mu^2 = \cdot0000021$) are respectively

$$+53x^2 - 13xy \text{ and } +53xy - 13y^2.$$

both multiplied by ·000001. Hence the outstanding residuals require correction by

$$-21x^2+3xy+16y^2 \text{ for } x$$

and

$$-\ 9x^2+xy-4y^2 \text{ for } y.$$

12. Calling these $Ax^2+Bxy+Cy^2$ and $Dx^2+Exy+Fy^2$, then if they were due to optical distortion, according to the criterion of the last paper, A, E, C should be of the same sign and in descending order numerically; also F, B, D should be of the same sign and in descending order. This is far from being the case, A and C being conspicuously of opposite signs.

13. On the other hand, if these corrections have their origin in errors of copying we should have

$$\frac{A}{D}=\frac{B}{E}=\frac{C}{F}.$$

These relations are not fulfilled as the numbers stand, but a small "error of normal" could be assigned which would make them fit, *e.g.* if X and Y above instead of being $(-25, +6)$ are really $(-21, +12)$, we should get for the theoretical corrections for difference of normals

$$+44x^2-25xy \text{ and } +44xy-25y^2,$$

and thus

$$Ax^2+Bxy+Cy^2=-12x^2+15xy+16y^2$$

$$Dx^2+Exy+Fy^2=-9x^2+10xy+8y^2$$

14. Of course this is introducing two new arbitrary constants, and we must therefore not attach too much importance to the result; but it is to be remarked that not even by this device can we make the expressions such as would arise from optical distortion, for we cannot make A of the same sign as C and numerically greater without assuming an extravagant error of normal, viz. 18 *réseau* intervals at least.

15. Hence it would appear from the study of the terms of the second order that not even at this increased distance from the centre of the Arequipa plate is there evidence of sensible optical distortion; such terms of this order as affect the residuals being due to errors of tilt or copying.

16. But, as above stated, my attention was recalled by a remark of Mr. Dyson to the linear terms which may theoretically be larger than those of the second order, with a certain law of optical distortion, and the study of them gave interesting results. In explanation of the fact that I have hitherto neglected them, I may remark that in commencing this rather new investigation my attention was naturally attracted by the newest thing which I encountered. Had no terms of the second order presented themselves, the linear terms would naturally have been carefully

examined. But terms of the second order (not due to a difference of centres) in the comparison of two plates were a new feature. In comparing our astrographic plates the relations are sensibly linear (except for any difference of centring), and in looking for optical distortion on these large plates taken with a doublet, which even near the centre could not be expressed in terms of our plates by linear relations, I felt that at any rate these terms of the second order must be explained, and they seemed to afford the quickest route to the solution of the problem. The time spent in studying them was in no way lost, for I doubt whether I should have come upon the errors of copying by study of the linear terms.

The Linear Terms.

17. Before examining the individual plates the nature of the problem may be briefly stated. Each Oxford plate has been compared with the theoretical sky in the course of the regular work at Oxford, and is therefore as good as a piece of sky, except for accidental errors. Each copy of a portion of the Arequipa plate has been compared with an Oxford plate and thus indirectly with the sky. The formula for reduction of a copy to the sky will include

(*a*) The effect of refraction for the Arequipa plate ;
(*b*) The effect of aberration for the Arequipa plate ;
(*c*) The scale value of the Arequipa plate ;
(*d*) An arbitrary orientation and error of centring of the particular copy ;
(*e*) The correction for scale of the particular copy due to its distance from the centre of the large plate ;
(*f*) the effect of optical distortion.

18. As regards (*b*) the effect of aberration to the first order is a simple change of scale, and hence it may be considered as included in (*c*).

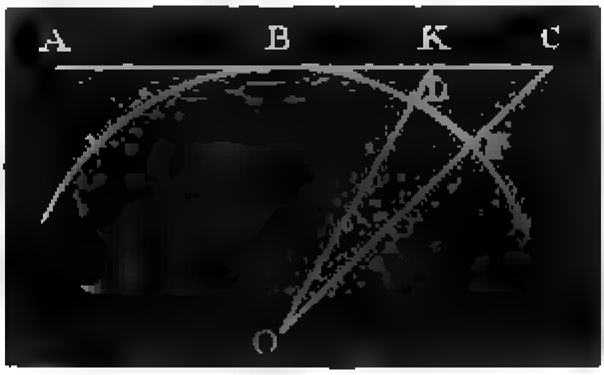


FIG. 2.

The correction (*e*) requires, perhaps, a little more explanation. Let A B C (fig. 2) be the large Arequipa plate. Then a portion, K C, far from the centre, is compared with an Oxford plate, which may be regarded as touching the celestial sphere at L F ; and

since K C is greater than L F, the scale of the Arequipa plate will in this region be relatively larger than at the centre B. The theoretical correction will be given later.

19. Coming to (*f*) the optical distortion, if there be displacements $\phi(x, y)$ and $\psi(x, y)$ in the coordinates x and y due to optical distortion, then in the neighbourhood of the point (ξ, η) these have the values

$$\phi(\xi, \eta) + x\phi + y\phi_\eta + \tfrac{1}{2}(x^2\phi_{\xi\xi} + 2xy\phi_{\xi\eta} + y^2\phi_{\eta\eta}) + \&c.,$$

with a similar expression for ψ, and the linear terms are thus

$$x\phi_\xi + y\phi_\eta \text{ and } x\psi_\xi + \eta\psi_\eta.$$

As in the previous paper (§ 35), if the displacement be along a radius from some centre, and vary as r^{n+1}, so that the displacements in x and y are $Pr^n x = \phi(x, y)$ and $Pr^n y = \psi(x, y)$, then

$$\phi_\xi = P(\rho^n + n\rho^{n-2}\xi^2) \qquad \phi_\eta = Pn\rho^{n-2}\xi\eta$$
$$\psi_\xi = Pn\rho^{n-2}\xi\eta \qquad \psi_\eta = P(\rho^n + n\rho^{n-2}\eta^2).$$

As regards the magnitude of these compared with terms of the second order, we may take as an instance

$$\phi_{\xi\xi} = nP\rho^{n-4}\xi\{3\rho^2 + (n-2)\xi^2\}.$$

Hence the ratio of $\frac{1}{2}\phi_{\xi\xi}x^2$ to $\phi_\xi \,.\, x$ is

$$\tfrac{1}{2}n\xi x\{3\rho^2 + (n-2)\xi^2\} \text{ to } \rho^2\{\rho^2 + n\xi^2\}.$$

The limiting cases are $\xi = \rho$ and $\xi = 0$. When $\xi = \rho$ the ratio is

$$\tfrac{1}{2}nx \text{ to } \rho.$$

When $\xi = 0$ the ratio is zero. Thus if n be large the terms of the second order are more important than the linear terms; but if n be small this is not so.

20. We proceed to the consideration of the three regions measured on the Arequipa plate, and compared with Oxford plates 1144, 835, and 207. In the first instance the Oxford measures, say x and y, were corrected to x' and y', values near those of the Arequipa copies, to help in readily identifying the proper stars. The values of $x' - x$ and $y' - y$ are given in §§ 26 and 45 of the former paper and § 9 of the present one, and are as below :

Plate.	$x' - x$.	$y' - y$.
1144	$-\cdot010x + \cdot002y$	$-\cdot002x - \cdot010y$
835	$-\cdot010x + \cdot003y$	$-\cdot003x - \cdot010y$
207	$-\cdot010x - \cdot004y$	$+\cdot004x - \cdot010y$

21. We then found that if (X, Y) denote measures on a copy of the Arequipa plate, and (x', y') denote the Oxford measures

corrected as above, the values of $X-x'$ and $Y-y'$ were as follows, omitting a constant:

Plate.	$X-x'$.	$Y-y'$.
1144	$+·00017X+·00000Y$	$-·00051X+·00014Y$
835	$-·00014X-·00019Y$	$+·00008X\quad ·00062Y$
207	$+·00169X+·00042Y$	$-·00092X+·00064Y$

22. Finally, in the course of the regular work at Oxford the following expressions were found for reduction of (x, y) to (ξ, η), the standard coordinates for stars in the theoretical sky:

Plate.	$x-\xi$.	$y-\eta$.
1144	$+·00750\xi+·01435\eta$	$-·01418\xi+·00756\eta$
835	$+·00835\xi+·00792\eta$	$-·00769\xi+·00826\eta$
207	$+·00781\xi+·00117\eta$	$-·00150\xi+·00791\eta$

23. We thus obtain for $X-\xi$ and $Y-\eta$ the following values:

Plate.	$X-\xi$	$Y-\eta$.
1144	$-·00244\xi+·01624\eta$	$-·01658\xi-·00242\eta$
835	$-·00189\xi+·01068\eta$	$-·01055\xi-·00246\eta$
207	$-·00058\xi-·00244\eta$	$+·00162\xi-·00153\eta$

There is thus a well-marked difference in scale value between the copies, but this is in great measure due to the cause specified in (*e*) of § 17, and we must now estimate this effect numerically.

24. The relations between coordinates (x_1y_1) on one plate and (x_2y_2) of the same star on another plate, whose centre is at (XY) on the first, are approximately

$$x_2=\frac{x_1-X}{1+Xx_1+Yy_1}\qquad y_2=\frac{y_1-Y}{1+Xx_1+Yy_1}$$

or

$$x_2(1+Xx_1+Yy_1)=x_1-X,$$

or substituting on the left

$$x_1=x_2+X \text{ and } y_1=y_2+Y$$

$$x_2(1+X^2+Y^2)+Xx_2^2+Yx_2y_2=x_1-X.$$

and similarly

$$y_2(1+X^2+Y^2)+Xx_2y_2+Yy_2^2=y_1-Y$$

Thus the change of scale is represented by the factor $(1+X^2+Y^2)$ and depends simply on the distance between centres, as it should. If X and Y are expressed in *réseau* intervals, we must multiply X^2+Y^2 by ·0000021, and the products for the three plates are (see § 9).

Plate.	Product.
1144	·00041
835	·00024
207	·00138

25. In applying these corrections we may at the same time rotate the axes so as to reduce the coefficients of y and x in x and y respectively. If these were exactly equal, and of opposite sign, we could make them both zero by a simple rotation of axis, writing

$$x_2 \text{ for } (1 - \tfrac{1}{2}\theta^2)x_1 - \theta y_1$$

and

$$y_2 \text{ for } + \theta x_1 + (1 - \tfrac{1}{2}\theta^2)y_1.$$

But the equality is only approximate, and we choose for θ the numerical mean of the two values, as below :

Plate.	$+\theta$.	$\frac{1}{2}\theta^2$.
1144	−·01641	·00013
835	−·01061	·00005
207	+·00203	·00000

26. The corrected values of $X-\xi$ and $Y-\eta$ thus become

Plate.	$X-\xi$.	$Y-\eta$.
1144	$-·00272\xi-·00017\eta$	$-·00017\xi-·00271\eta$
835	$-·00228\xi+·00007\eta$	$+·00006\xi-·00265\eta$
207	$-·00196\xi-·00041\eta$	$-·00041\xi-·00291\eta$

27. The correction for differential refraction on the Arequipa plate must now be calculated (the refraction and aberration for the Oxford plates are included in the formulæ, reducing them to the theoretical sky). Particulars are given in § 50 of the preceding paper for calculating X_0, Y_0, the coordinates of the zenith on the Arequipa plate, which are thus found to be $X_0 = -0·44$ and $Y_0 = -0·99$; and the corrections for differential refraction to the first order, viz.

$$+\mu(1+X_0^2)X + \mu X_0 Y_0 . Y \text{ in } x$$

and

$$+\mu X_0 Y_0 . X + \mu(1+Y_0^2)Y \text{ in } y$$

(where μ is the coefficient of refraction and may be taken as $57''$, ·00028 in circular measure) thus become

$$+·00033X + ·00011Y \text{ and } +·00011X + ·00054Y.$$

The effect of refraction is to decrease X and Y by these expressions : and hence the measured X and Y are too small to this extent. To compare X and Y with ξ and η as if there were no refraction we must therefore add the above expressions to X and Y, making $X-\xi$ and $Y-\eta$ larger in consequence, as below.

Plate.	$X-\xi$.	$Y-\eta$.
1144	$-·00239\xi-·00006\eta$	$-·00006\xi-·00217\eta$
835	$-·00195\xi+·00018\eta$	$+·00017\xi-·00211\eta$
207	$-·00163\xi-·00030\eta$	$-·00030\xi-·00237\eta$

28. If there were no optical distortion, then denoting the value of

$$X-\xi \text{ by } a_1\xi+b_1\eta,\ a_2\xi+b_2\eta, \text{ \&c.}$$

and of

$$Y-\eta \text{ by } +b_1\xi+e_1\eta,\ +b_2\xi+e_2\eta, \text{ \&c.}$$

we should expect $a_1=a_2=a_3=e_1=e_2=e_3$, and $b_1=b_2=b_3=0$. The departure from this state of things is quite sensible, and it remains to examine whether the departure can be attributed to optical distortion.

29. The values of the coefficients a, b, and e have been given in § 19; but the symbols there employed have since been used in rather different senses. Let us put (u, v) for the coordinates of the centre of a plate or region referred to the optical centre, and let $r^2=u^2+v^2$. Then if the distortion is Pr^n, we have the following values for the coefficients a, b, and e:—

$$a=Pr^{n-2}(r^2+nu^2),\quad b=Pnr^{n-2}.uv,\quad e=Pr^{n-2}(r^2+nv^2).$$

Thus

$$\frac{a-e}{b}=\frac{u^2-v^2}{uv},$$

a relation which is independent of n, and affords a simple test of the existence of this kind of optical distortion.

30. Assuming that the optical centre is at the centre of the Arequipa plate, the values of u and v for the three plates are given in § 9 under the head x and y: and the following tabular statement shows how far the above relation is fulfilled.

Plate.	$a-e$.	b.	$\frac{a-e}{b}$	u^2-v^2	uv	$\frac{u^2-v^2}{uv}$
1144	−·00022	−·00006	+3·7	+ 95	− 98	−1·0
835	+·00016	+·00017	+1·0	+ 45	+ 54	+0·8
207	+·00074	−·00030	−2·5	+589	−150	−3·9

There is a considerable discrepancy in the case of Plate 1144; but the coefficient b is small, and may be largely accidental. It may be remembered that this plate is a good deal affected by errors of copying.

31. Since $b/uv=Pnr^{n-2}$, a comparison of the three values of b/uv should be some guide to the value of n. Take the second and third plates, which seem fairly accordant. The values of b/uv are in the ratio 31 to 20, which is $(r_2/r_3)^{n-2}$. But $r_2/r_3=11/26$. This suggests that $n-2$ is negative, the actual value given by this relation being $n-2=-0·5$ or $n=1·5$. If for the same plates we took $(a-e)/(u^2-v^2)$, which should also give Pnr^{n-2}, the ratio is 36 to 13, giving $n-2=-1·2$ or $n=0·8$. Hence the value $n=1$, implying a law of displacement $=Pr^2$, with displacements Prx and Pry in x and y, does not seem unlikely.

32. Calculating on this supposition

$$\frac{a}{P} = r + \frac{u^2}{r}, \quad \frac{b}{P} = \frac{uv}{r}, \quad \frac{e}{P} = r + \frac{v^2}{r}$$

for the three plates, we get the following values :

Plate.	a	b	$\frac{e}{P}$
1144	+24	−6	+17
835	+18	+5	+14
207	+51	−6	+27

33. It remains to assign the value of P. From consideration of this table in conjunction with that of § 27, we may put P = + ·00002, and then subtract these theoretical values of a, b, and e from those of § 27. If this law of distortion is satisfactory, we ought then to get the values of a and e all equal, and the values of b all zero. The old values and the new are collected in the following table. To show more clearly the differences of a and e, the mean value −210 has been subtracted from all the old values, and the mean value −261 from all the new values ; the unit is as before, ·00001.

Plate.	Old Values.			New Values.		
	a	e	b	a	e	b
1144	−29	− 7	− 6	−26	+10	+ 6
835	+15	− 1	+18	+30	+22	+ 8
207	+47	−27	−30	− 4	−30	−18

34. We have not therefore improved things very much. The mean numerical value of b is reduced from 18 to 11, but that of a and e only alters from 21 to 20. Nor can we get any much better result by taking another value of n : it can be shown that there is an inherent difficulty in satisfying the conditions, independent of n. For write the old values of a and e which it is desired to bring into accordance in the order of magnitude, viz. +47 +15 −1 −7 −27 −29, then the corresponding expressions $Pr^{n-2}(r^2+nu^2)$ &c. (see § 29) should fall into approximately the same order. Picking these out, and substituting the values of u, v, and r, from § 9 we get the following series, which should be in order of magnitude.

$$26^n(1+\cdot 8n),\ 11^n(1+\cdot 8n),\ 11^n(1+\cdot 3n),\ 14^n(1+\cdot 3n),\ 26^n(1+1n),\ 14^n(1+\cdot 8n)$$

When n is small we may take logarithms to base e, and neglecting powers of n above the first we can divide out by n. Thus the first term is n (log. 26+·8), and dividing by n the following numbers should be in order :—

1·8 0·9 0·4 0·7 1·1 1·1

which is not even approximately the case. Large values of n are excluded by other considerations.

35. Hence it is no easier to detect optical distortion in the linear terms than in those of the second order, and we must regard the discrepancies as due to accidental causes—perhaps errors of copying—in the same way as the second order terms.

36. Thus we may feel some confidence that the optical distortion over a considerable field is small; and that accurate positions of stars may be obtained from these large plates if proper precautions be taken. I do not think, however, that the present line of examination is the best way of arriving at precise information about a small optical distortion; the method of trails, mentioned by Captain Hills, R.E., at the April meeting of the Society, seems better.

In another paper I have examined the necessary formulæ of reduction, and find them very simple; and I think the method will prove to be a very easy and direct way of measuring the optical distortion of a lens. The foregoing investigations will, however, serve to show how two plates may be compared when we have no independent information as to the optical distortion.

Conclusions of the Present Paper.

1. The errors of copying due to curvature of plate and oblique illumination, suggested in the last paper, were reproduced by direct experiment. The numerical value found was smaller than was expected, though this is capable of explanation. (§§ 1–7.)

2. A third region, including stars up to 4° from the centre of the Arequipa plate, was compared with an Oxford plate, and the terms of the second order gave no evidence of optical distortion. (§§ 8–15.)

3. The terms of the first order for all three plates dealt with in this paper and the last were examined, and gave no evidence of optical distortion. (§§ 16–35.)

4. Hence it seems possible to obtain good results over a region of (say) $5° \times 5°$ with a photographic doublet.

5. Further experiments are, however, desirable by the method of star-trails, as indicated elsewhere

On the Curvature of Star-trails on a Photographic Plate as a Means of Investigating Optical Distortion. By H. H. Turner, M.A., F.R.S., Savilian Professor.

1. In the discussion on my paper on optical distortion, read at the April meeting of the Society, Captain Hills, R.E., mentioned a simple method of investigating the distortion on a wide-angle photograph, which he had used in practice viz. to take a series of star-trails on the plate and to compare their curvature with

the theoretical curvature. If the field be not too large, the theoretical curvature is easily calculated from the formula

$$y = x^2 \times \tfrac{1}{2} \tan \delta,$$

where x y are expressed in circular measure.

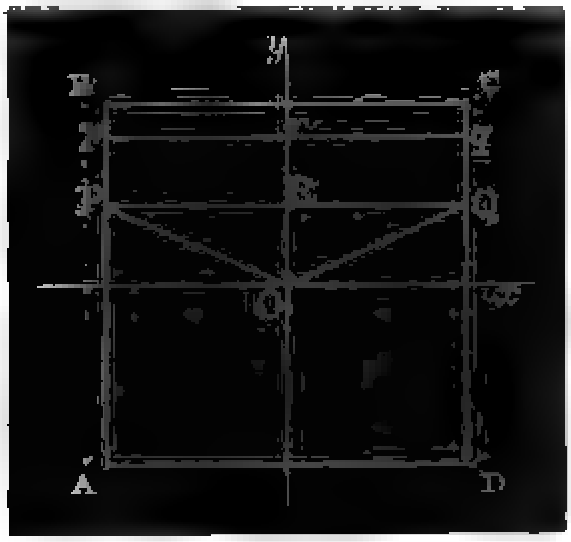
But with large fields it becomes necessary to employ a more accurate formula and to correct for refraction. If spherical co-ordinates are employed such formulæ are troublesome, but with rectangular coordinates they can be put into a simple form.

2. Let us consider first how optical distortion would affect the curvature of trails in different parts of the plate. We shall suppose the distortion to be a displacement of points along the radius from the centre of the field, and varying as some power of the radius. To fix the ideas, let us suppose it varies as the cube of the radius, so that

$$\Delta r = \mathrm{A} r^3,$$

and thus

$$\Delta x = \mathrm{A} r^2 x, \qquad \Delta y = \mathrm{A} r^2 y.$$



Let A B C D be a plate centre O, axes x and y parallel and perpendicular to the trails, which are nearly straight.

Let P R Q be a trail; and let

$$\mathrm{QR} = \mathrm{RP} = x, \quad \mathrm{OR} = y$$

Then distortion, which increases any ordinate y by $\Delta y \equiv \mathrm{A} r^2 y$, elevates

$$\mathrm{P} \text{ and } \mathrm{Q} \text{ by } \mathrm{A}(x^2 + y^2)\, y, \text{ and } \mathrm{R} \text{ by } \mathrm{A} y^3 \text{ only,}$$

so that the depth of R below P Q is increased by

$$\mathrm{A} x^2 y \text{ (approximately).}$$

If we take another trail, prq, higher up the plate, with ordinate y', the effect of distortion on its curvature will be

Ax^2y; and thus the distortion affects the curvatures more and more as the trails travel up the plate in direct ratio to the distance.

Had we selected another law of distortion, say $\Delta r = Ar^5$, we should have had for the effect on curvature

$$\begin{aligned} &A(x^2+y^2)^2y - Ay^5 \\ &= A(x^4+2x^2y^2)y, \end{aligned}$$

which varies more rapidly than the first power of y at a distance from the centre. If we take even powers of r for Δr, such as

$$\Delta r = Ar^2 \text{ or } Ar^4,$$

we cannot express the effect of curvature as a finite series of powers of x and y; but the general run of the effect will be intermediate in character between that of two odd powers.

3. Thus we must be prepared to deal with trails in all parts of the plate, *i.e.* x and y may have values corresponding to the corners of the plate. We must now settle how big a plate we are going to measure. Suppose the plate something over 11° square, so that the coordinates of the corners, measured from the centre, are $\pm 0{\cdot}1$ in circular measure. The maximum value of successive powers and products of x and y is then shown in the following table:—

Circular Measure.	Arc.	Circular Measure.	Arc.
$x = 0{\cdot}1$	345'·0	$x^4 = {\cdot}0001$	20''·7
$x^2 = 0{\cdot}01$	34'·5	$x^5 = {\cdot}00001$	2·1
$x^3 = 0{\cdot}001$	3·5	$x^6 = {\cdot}000001$	·21
		$x^7 = {\cdot}0000001$	·02

On such plates we may certainly reject x^7 and higher powers without any loss of accuracy, perhaps even x^6, but the computations will be carried out as far as x^6.

Plates larger (in angular field) than this have been used; and we may readily estimate the effect of going beyond this limit. Suppose, for example, that the plate is four times this area, *i.e.* 23° × 23°. Then x^7 would represent in the corners 2''·6. Now this is not a *very* large error to make as a maximum in a plate with this immense field, for unless the plate is of very large actual size, the scale must be comparatively small. For instance, the plate is unlikely to be larger than 23 inches × 23 inches, or 1 inch to the degree, one-third the scale of the Astrographic Catalogue plates; so that neglecting 2''·6 in the corners is equivalent to neglecting 0''·9 in the corners of Catalogue plates. Thus, though the formulæ developed in the following paragraphs are strictly accurate only for plates not larger than 11° × 11°, still they are probably accurate enough for *any* plate likely to be taken. If exceptionally

large plates are taken in the future, the calculations can easily be extended for these exceptional cases.

4. *Theoretical Curvature without Refraction.*—The standard coordinates of a star on a plate are given by the following formulæ (*Monthly Notices*, liv. p. 17):—

$$\xi = \tan(\alpha - A)\sin q \sec(P - q), \quad \eta = \tan(P - q),$$

where

$$\tan q = \tan p \cos(\alpha - A),$$

α and p being the R.A. and N.P.D. of the star,
A and P " " " plate centre.

To get the relation between ξ and η for a trail, we must eliminate $(\alpha - A)$ between these two equations. The result may be set down without taking up space with the working; and since we shall be dealing with stars near the Equator, it will be more convenient to substitute $90° - \delta$ and $90° - D$ for p and P respectively. The equation to a "trail" is thus found to be

$$\xi^2 \sin^2\delta = [\eta\cos(\delta - D) - \sin(\delta - D)][\eta\cos(\delta + D) + \sin(\delta + D)].$$

When

$$\xi = 0, \quad \eta = \tan(\delta - D), \text{ or } -\tan(\delta + D).$$

The case with which we are concerned is the former, the latter root referring to the lower culmination of the star in the meridian of the plate.

Put $\eta = \tan(\delta - D) + z$, where z is small.

The equation becomes

$$\xi^2 \sin^2\delta = z \sin 2\delta + z^2 \cos(\delta - D)\cos(\delta + D),$$

or

$$z = \tfrac{1}{2}\tan\delta \,.\, \xi^2 - z^2 \cos(\delta - D)\cos(\delta + D)\operatorname{cosec} 2\delta.$$

5. At first sight it would seem that the second term on the right is large when δ is small; but z^2 cosec 2δ is always small, and hence the term is small. Neglecting it gives the usual expression for curvature quoted in §1.

If we put

$$z \cot\delta = u,$$

then

$$u = \tfrac{1}{2}[\xi^2 - u^2 \cos(\delta - D)\cos(\delta + D)\sec^2\delta]$$
$$= \tfrac{1}{2}[\xi^2 - u^2(1 - \sin^2 D \sec^2\delta)].$$

6. Thus when D=0, if we put u_0 for the value of u,

$$u_0 = \tfrac{1}{2}[\xi^2 - u_0^2]$$

or

$$u_0^2 + 2u_0 - \xi^2 = 0:$$
$$\therefore u_0 = (1 + \xi^2)^{\frac{1}{2}} - 1$$
$$= \tfrac{1}{2}\xi^2 - \tfrac{1}{8}\xi^4 + \tfrac{1}{16}\xi^6.$$

Thus

$$z = [\tfrac{1}{2}\xi^2 - \tfrac{1}{8}\xi^4 + \tfrac{1}{16}\xi^6] \tan \delta.$$

Referring to the table in §3, we see that the maximum value of $\frac{1}{16}\xi^6$ is $0''\cdot01$, and we may therefore reject this term. Since δ is small the term $\frac{1}{8}\xi^4 \tan \delta$ is also small, and the formula

$$z = \tfrac{1}{2}\xi^2 \tan \delta$$

is very accurate even for large plates.

7. When D is not zero, but at the same time D and δ are less than 45°, then putting

$$\kappa = 1 - \sin^2 D \sec^2 \delta,$$

we have

$$\kappa u^2 + 2u - \xi^2 = 0,$$

$$u = \frac{1}{\kappa}\{\sqrt{1 + \kappa\xi^2} - 1\},$$

$$= \tfrac{1}{2}\xi^2 - \frac{\kappa}{8}\xi^4 + \frac{\kappa^2}{16}\xi^6;$$

$$z = \left[\tfrac{1}{2}\xi^2 - \frac{\kappa}{8}\xi^4 + \frac{\kappa^2}{16}\xi^6\right] \tan \delta.$$

Since κ^2 is less than unity, the term $\dfrac{\kappa^2}{16}\xi^6$ can be rejected still more than before; and thus

$$z = \left(\tfrac{1}{2}\xi^2 - \frac{\kappa}{8}\xi^4\right) \tan \delta$$

is an accurate formula for trails when δ and D lie between 0° and 45°.

8. But in experiments on optical distortion we do not need the absolute curvature of a trail, only the *difference* of curvatures between trails in the middle of the plate and elsewhere; and in many instances we do not require any formula at all. There are two distinct cases likely to occur in practice.

(A) When trails of the same star are taken in different portions of the plate; *i.e.* δ remains constant, and D varies from $\delta + 5°\cdot7$ to $\delta - 5°\cdot7$.

(B) When the plate centre is kept fixed and different stars allowed to trail over it; here D is kept fixed and δ varies from $D + 5°\cdot7$ to $D - 5°\cdot7$.

9. Take Case A first. Let $D = \delta + \eta$. Then $\eta < 5°\cdot7$ and

$$\begin{aligned}\kappa &= 1 - \sin^2(\delta + \eta)\sec^2\delta \\ &= 1 - \tan^2\delta - 2\eta\tan\delta \\ &= \kappa_0 - 2\eta\tan\delta, \text{ say.}\end{aligned}$$

Let z_0 refer to a trail through the plate centre. Then

$$z_0 = \left(\tfrac{1}{2}\xi^2 - \frac{\kappa_0}{8}\xi^4\right)\tan\delta$$

$$z = \left(\tfrac{1}{2}\xi^2 - \frac{\kappa_0 - 2\eta\tan\delta}{8}\xi^4\right)\tan\delta\,;$$

$$\therefore\ z - z_0 = +\tfrac{1}{4}\eta\,.\tan^2\delta\,.\,\xi^4.$$

10. When $\delta = 45°$ the maximum value of this expression, *i.e.* its value when $\xi = 0{\cdot}1$, and $\eta = 0{\cdot}1$ is $0''{\cdot}5$ (see § 3); and thus for work in which we reject quantities less than $1''{\cdot}0$ we may consider trails of the same star to have the same theoretical curvature all over the plate. For more accurate work we may use the following small table :—

Table of differences of curvature for trails of the same star in different parts of a plate.

If the trail be m degrees *south* of the plate centre, and $2n$ degrees long from end to end, and if the height of the ends above the middle be measured in seconds of arc and compared with a similar result for a trail of the same star through the plate centre, the excess of the former above the latter is $mn^4 \times {\cdot}00001$ times the quantity tabulated below.

Decl. of Star.	Excess.	Decl. of Star.	Excess.
°	″	°	″
10	+0·3	37·5	+4·8
20	+0·8	40·0	+6·0
30	+2·3	42·5	+7·1
35	+4·2	45·0	+8·4

11. (B) If we expose the same plate to a series of stars of different declinations, without moving the plate centre, the calculation is not so simple. For the curvatures of two stars declinations δ_1 and δ_2 will differ by a quantity of a different order, viz.:

$$\tfrac{1}{2}\,\xi^2\,(\tan\delta_1 - \tan\delta_2).$$

But using the table of Case A to reduce the curvature to the value it would have had if the trail had gone through the plate centre, we can now form tables for stars of different declinations giving the curvature of their trails when central on a plate. In fact we have to tabulate z_0 of the preceding case, viz.:

$$z_0 = \tfrac{1}{2}\tan\delta\,.\,\xi^2 - \tfrac{1}{8}(\tan\delta - \tan^3\delta)\,\xi^4.$$

The maximum value of the coefficient of ξ^4, which vanishes when $\delta = 0°$ and $\delta = 45°$, occurs when $3\tan^2\delta = 1$, *i.e.* for $\delta = 30°$; and its value is then $0{\cdot}048$, the effect on z_0 being $1''{\cdot}0$.

12. Thus if we are neglecting quantities less than 1″, we may neglect this term altogether; *i.e.* combining this result with that of the last paragraph we may say that

The formula $z=\frac{1}{2}\tan\delta\,.\,\xi^2$ *gives the curvature of all star trails on plates not larger than* 11° × 11° *wherever they may be on the plate, when* δ *lies between* 0° *and* 45° *with errors less than* 1″.

13. For more accurate work it is not difficult or troublesome to calculate the two coefficients of § 11; but a small table of $\frac{1}{\mu}(\tan\delta - \tan^3\delta)$ will help, and then we can include both Cases A and B under one general formula, as follows:

Let δ be the declination of a star and let its trail be $2n$ degrees long, and m degrees south of the plate centre. The height of the ends above the middle in seconds of arc is given by

$$z=31''\cdot416\,.\,n^2\,.\,\tan\delta+(mn^2\,.\,A\,.+n^4B)\times0\cdot00001,$$

where A and B are given in the following table:

$\delta=$	A	B	$\delta=$	A	B
°	″	″	°	″	″
0	+0·0	0·0	25	+1·4	43·5
5	+0·1	10·4	30	+2·3	46·2
10	+0·3	20·5	35	+4·2	42·8
15	+0·6	29·9	40	+6·0	29·9
20	+0·8	37·9	45	+8·4	0·0

14. *Refraction.*—We have now to examine what effect refraction has upon the curvature of a trail. In *Monthly Notices*, lvii. pp. 133, &c., it is shown that the effect of a refraction μ . tan Z.D. on a star whose coordinates are (x, y) when the coordinates of the zenith on the plate (supposed extended in the same plane so as to include the zenith) are (X, Y) is to increase x and y by Δx and Δy where

$$\Delta x=T(X-x)\quad \Delta y=T(Y-y)$$

and

$$T=\frac{\mu(1+x^2+y^2)}{1+Xx+Yy}$$

(T being the same as $-t$ in the paper cited, p. 136).

Now $\mu=57''$ approximately; hence for our plates the max. value of $\mu x^3=0''\cdot057$. There is no doubt we may reject μx^4, but μx^3, especially if multiplied by 2 or 3, might introduce errors. Fortunately third powers of x and y do not occur in the present investigation, for we find the curvature of a trail by measuring the dip of the middle below the ends. If the effect of refraction be

$$a_0+a_1x+a_2x^2+a_3x^3+a_4x^4+,\ \&c.,$$

then at one end $x=+\xi$, and at the other $x=-\xi$, so that for the mean of the two the effect is

$$a_0+a_2\xi^2+a_4\xi^4+,\ \&c.,$$

and for the middle where $x=0$ the effect is a_0. Thus the effect on the height of ends above middle is

$$a_2\xi^2+a_4\xi^4,$$

and since we may certainly reject fourth powers we need only consider the term $a_2\xi^2$.

15. We assume that X and Y are not much greater than unity; *i.e.* that the plate is exposed at a Z.D. not much greater than 45°.

Then

$$\frac{1}{\mu}\mathrm{T}=(1+x^2+y^2)(1+\mathrm{X}x+\mathrm{Y}y)^{-1}$$

$$=[1-\mathrm{X}x-\mathrm{Y}y+x^2(1+\mathrm{X}^2)+2\mathrm{XY}xy+y^2(1+\mathrm{Y}^2)],$$

and

$$\frac{1}{\mu}\Delta y=\mathrm{Y}-y(1+\mathrm{Y}^2)-x\mathrm{XY}+x^2(1+\mathrm{X}^2)+xy(\mathrm{X}+2\mathrm{XY})+y^2(1+\mathrm{Y}+\mathrm{Y}^2).$$

In this we put from § 8

$$y=y_0+\tfrac{1}{2}\tan\delta\, x^2,$$

and thus the coefficient of x^2 in $\frac{1}{\mu}\Delta y$ is

$$-\tfrac{1}{2}\tan\delta\,(1+\mathrm{Y}^2)+(1+\mathrm{X}^2)+y_0\tan\delta\,(1+\mathrm{Y}+\mathrm{Y}^2).$$

The last term is equivalent to a term in x^3, since y_0 is liable to the same maximum value as x. And if $\mathrm{Y}=1$, $\tan\delta=1$ we may thus have from this term as much as $3\times 0''\cdot057=0''\cdot17$. But under most conditions either $\tan\delta$ or Y would be small. We can, in fact, always expose a plate tolerably near the zenith if δ may be as much as 45°; and hence we shall neglect the term $y_0\tan\delta\,(1+\mathrm{Y}+\mathrm{Y}^2)$.

Thus the effect of refraction on curvature is expressed by

$$z=\mu[(1+\mathrm{X}^2)-\tfrac{1}{2}\tan\delta\,(1+\mathrm{Y}^2)]\xi^2.$$

16. Now if the plate centre be kept fixed as in Case B of § 11, and different stars allowed to trail across it, then X and Y remain the same and $\tan\delta$ varies from $\mathrm{D}-5^\circ\cdot7$ to $\mathrm{D}+5^\circ\cdot7$. Thus the difference in the values of z at the edges is

$$z_1-z_2=\frac{\mu}{2}(\tan\delta_2-\tan\delta_1)(1+\mathrm{Y}^2)\xi^2$$

$$=\frac{\mu}{2}\sec^2\mathrm{D}\times 0\cdot2(1+\mathrm{Y}^2)\xi^2 \text{ approx.}$$

The factor $\sec^2\mathrm{D}(1+\mathrm{Y}^2)$ is not much greater than unity; and since the maximum value of $\mu\times 0\cdot1\times\xi^2$ is $0''\cdot056$, we may in general neglect this difference. Hence

O O

If various trails be taken on a plate 11°·5 × 11°·5 whose centre is kept fixed and exposed to a point within 45° of the zenith, the curvatures of all trails will be equally affected by refraction, if quantities under 0″·1 be neglected.

17. If, however, the same star be used but the plate centre moved about so as to take different trails of it, then X and Y vary, but tan δ remains constant. In this case

$$z_1 - z_2 = \mu\xi^2[(X_1^2 - X_2^2) - \tfrac{1}{2}\tan\delta\,(Y_1^2 - Y_2^2)].$$

When X_1, X_2, and Y_1, Y_2 are not very different this will be small. If the plate be exposed within 45° of the zenith, X_1, X_2, Y_1 and Y_2 are all less than unity; and since $\mu\xi^2$ has the value 0″·57 at maximum, we are not liable to an error greater than this if we neglect the effect of refraction entirely. For some work this knowledge is sufficient. For instance, in his Memoir * on the determination of longitudes by photography, Captain Hills neglects all quantities less than 1″; so that for his work the effect of refraction on the trails, whether of the same star or of different stars, may be neglected entirely, provided the plates be exposed at a Z.D. not greater than 45°.

18. For more accurate work we may examine the above expression a little more closely. The coordinates X and Y are determined from the equations

$$X = -\tan h \sin q \sec (P - q) \quad Y = \tan (P - q),$$

where

$$\tan q = \tan \lambda \cos h$$

and h is the hour angle of the plate centre, λ the colatitude.

Now we shall suppose the plate exposed within a couple of hours of the meridian either way, which gives four working hours. Then the maximum value of h is ·5; of h^2 ·25; and of h^4 ·06. Thus as an approximation we may take

$$q = \lambda - \tfrac{1}{4}h^2 \sin 2\lambda$$

$$X = -h \sin \lambda \sec (P - \lambda) - h^3 \{\tfrac{1}{3} - \tfrac{1}{2} \cos \lambda \cos P \sec (P - \lambda)\}$$

$$Y = \tan (P - \lambda) + \tfrac{1}{4}h^2 \sin 2\lambda \sec^2(P - \lambda) + \text{fourth powers.}$$

Thus, if we neglect h^4, we may write

$$X^2 = h^2 \sin^2\lambda \sec^2(P - \lambda)$$

$$Y^2 = \tan^2(P - \lambda) + \tfrac{1}{2}h^2 \sin 2\lambda \tan (P - \lambda) \sec^2(P - \lambda).$$

Now $P - \lambda$ is the meridian Z.D. of the plate centre. But it is readily seen that we shall not make a sensible error if we substi-

* *Memoirs of Royal Astronomical Society*, vol. liii. p. 117.

tute for this $p-\lambda$, the meridian Z.D. of the star. Call this ζ. Then

$$Y_1^2 = \tan^2\zeta + \tfrac{1}{2}h_1^2 \sin 2\lambda \tan \zeta \sec^2\zeta$$

$$Y_2^2 = \tan^2\zeta + \tfrac{1}{2}h_2^2 \sin 2\lambda \tan \zeta \sec^2\zeta$$

$$\therefore \tfrac{1}{2} \tan \delta \,(Y_1^2 - Y_2^2) = \tfrac{1}{4}(h_1^2 - h_2^2) \sin 2\lambda \tan \delta \tan \zeta \sec^2\zeta.$$

Now for ordinary latitudes, such as those of Europe, the product $\tan \delta \tan \zeta$ is small. For stars near the equator δ is small, and for stars of declination $45°$, ζ is small. The maximum value of $\tan \delta \tan \zeta$ subject to the condition

$$\delta + \zeta = 90° - \lambda = \phi \text{ (the latitude)}$$

is $\tan^2\tfrac{1}{2}\phi$; the value of which is as follows :—

Latitude =	30°	40°	50°	60°
$\tan^2\frac{1}{2}\phi$	·07	·13	·22	·34

Also $h_1^2 - h_2^2$ is not greater than ·25. Hence we can neglect the terms depending on Y.

As regards $X_1^2 - X_2^2 = (h_1^2 - h_2^2) \sin^2\lambda \sec^2\zeta$, the maximum value of this term, when $h_2 = 0$ and $h_1^2 = \cdot 25$, is about ·25, and the effect on the refraction is about $0''\cdot 14$. We may fairly neglect such small quantities except for the most refined investigations.

Thus in this case also the trails are equally affected by refraction in all parts of the plate, if the exposures be confined to the two hours preceding and the two hours following the meridian and the star be between the equator and the zenith.

Conclusions.

(*a*) Let a trail of a star declination δ be taken on a plate of field $11°\cdot 5 \times 11°\cdot 5$, whose centre is in declination D; and let (X, Y) be the standard coordinates of the zenith on the plate. Then the equation to the trail in standard coordinates (ξ, η) expressed in circular measure, is

$$\begin{aligned} \eta &= \tan(\delta - D) \\ &\quad + \tfrac{1}{2} \tan \delta \,.\, \xi^2 \\ &\quad - \tfrac{1}{8} (\tan \delta - \tan^3\delta)\, \xi^4 && \text{(max. value } 1''\cdot 0) \\ &\quad - \tfrac{1}{4} \tan^2\delta \,.\, \tan(\delta - D) \,.\, \xi^4 && \text{(max. value } 0''\cdot 5) \\ &\quad + \mu\, [(1 + X^2) - \tfrac{1}{2} \tan \delta\, (1 + Y^2)]\xi^2 && \text{(max. value about } 0''\cdot 6). \end{aligned}$$

(*b*) If the exposures be at Z.D. less than 45°, and within two hours of the meridian, and if we take the *difference* between trails and not a single trail only, then the fifth line, due to refraction, may always be neglected, even for measurements of considerable precision.

(*c*) Under the conditions specified in (*b*) the third and fourth lines are quickly calculated by the table in § 13.

(*d*) If, further, the trails be of the same star, we need *only the fourth line*, as given by the little table of § 10.

(*e*) If we neglect quantities less than 1″·0, then the curvatures of all trails on a plate exposed near the meridian between D=0° and D=45° should be the same, unless there is optical distortion.

Remarks on the Paper by Professor W. Schur, together with determination of the Diameter and Polar Compression of the Planet Mars from Observations with the Repsold Heliometer of the Remeis Observatory, Bamberg, and with the Breslau Heliometer at the Observatory, Strassburg, in 1879. By Dr. Ernst Hartwig.

(*Communicated by the Secretaries.*)

In the March number of the *Monthly Notices* (p. 330) Professor Schur has communicated a series of heliometer measurements of the polar and equatorial diameters of the planet *Mars*, from which he deduces a polar compression of a fiftieth. In that discussion no reference is made to the probable errors of the results which are said to be of a greater weight than the earlier researches because an ocular reversing prism was used. Computing the mean errors for the single measures and for the results of one day I have found them (in spite of "images being steady") greater than they were in the measurements made by the same observer with the little Breslau heliometer at Strassburg in 1877. The mean error of a diameter reduced to mean distance of the planet *Mars* from the Sun is for the polar diameter ±0″·112, for the equatorial ±0″·094 (in mean distance Sun—Earth ±0″·170 and ±0″·143), therefore for the measured diameter ±0″·23 and ±0″·19, or for a distance of *Mars* the same as in 1877 ±0″·454 and ±0″·378, the corresponding mean errors in 1877 having been for the measures made by Dr. Schur with the Breslau heliometer ±0″·208 and ±0″·207.

The three days of 1899 give a mean difference of 0″·170 between both directions (polar and equatorial) for the diameter in the mean distance between Sun and Earth, and the mean error of it is ±0″·128, because the single difference has the mean error ±0″·222. The measures in 1896 are better, the mean error for the result of a day being (polar diameter) ±0″·031 and (equatorial diameter) ±0″·064 in mean distance of the Earth from the Sun, whence we find for the single difference the mean error ±0″·071, and for the mean, 0″·205, of the four differences the mean error ±0″·036. But the measures in 1899 in view of the great uncertainty do not prove that the compression is in conflict with

that which Hermann Struve has calculated from his researches on the motions of the apsides of the satellites *Phobos* and *Deimos*; and the measures in 1896 disagree with those in 1899 made by myself, which are independent of errors in estimation. I have also measured the diameter of *Mars* with the great Repsold heliometer of the Remeis Observatory since 1890, using the ocular reversing prism to eliminate the personal errors in measuring diameters of discs in different directions with respect to the vertical line. The bad conditions of atmosphere have prevented my getting more than one opportunity for measuring in both directions in each opposition 1890 and 1899. The measures, all made with apparent vertical motion of the images by means of the ocular reversing prism and corrected for defect of illumination, which I have directly computed in Bessel's manner, are the following:—

Date, 1890 (♂ May 27).	Mean Time, Bamberg.	Position-Angle. Observed.	Computed.	Measured Diameter.	Diameter at Mean Distance Sun—Earth.
	h m	°	°	″	″
May 6	12 46	54·2	36·3	16·522	9·222
	13 0	144·2	126·3	16·904	9·435
	13 14	144·2	126·3	16·828	9·393
	13 29	54·2	36·3	16·773	9·362
1894 (♂ Oct. 20).					
July 24	14 57	156·8	126·8	12·757	9·338
Aug. 26	16 52	156·9	129·9	16·351	9·196*
Sept. 14	13 55	156·3	130·2	19·437	9·424
1899 (♂ Jan. 18).					
Feb. 4	9 48	350·9	345·3	13·356	9·278
	10 2	260·9	255·3	13·447	9·340
	10 15	260·9	255·3	13·533	9·401
	10 37	350·9	345·3	13·333	9·262
Feb. 21	10 42	345·2	343·3	11·629	9·205†

whence we have

	Polar Diameter.	Equatorial.	$2a-2b$	$\frac{a-b}{a}$
	″	″	″	
1890	9·292	9·414	0·122	$\frac{1}{77}$
1899	9·270	9·370	0·100	$\frac{1}{94}$

Neglecting the deviation in areographic latitude ‡ the mean of the differences is 0″·111. The mean error of a measure for the polar diameter from observations 1890, 1894, and 1899 is ±0″·068, and if we assume the same mean error for the equatorial diameter, we get for the mean error of a single difference ±0″·096 and

* In daylight. † Only measured for position-angle.

‡ The areographic latitude 90°, in the paper of Professor Schur, is not right, because the middle of the disc of *Mars* was 13°·6 north of its equator at opposition, January 18.

of the mean of the two differences $\pm 0''\cdot068$, essentially less than the value of the difference itself; therefore a polar compression seems to exist and not to be in too great discordance with the theoretical value. In the *Ast. Nach.* 2272 I drew attention to the extremely good opportunity afforded by the opposition of 1879 for measuring the polar and equatorial diameter of *Mars*, each in both vertical and horizontal directions at eastern and western hour-angles. I have made a large series of measurements with the Breslau heliometer at Strassburg, the results of which will appear shortly in the *Astron. Nachrichten.* Herewith I have the honour to communicate the results of measurements of both diameters, obtained near the opposition of 1879. By *v* and *h* are denoted vertical and horizontal direction of the rotation axis, and by × an inclination of nearly 45°, when *Mars* was passing the meridian.

Date, 1879.	Mean Time, Greenwich.	Rotation Axis.	Diameter— Polar.	Diameter— Equatorial.	Diameter at Mean Distance, Sun—Earth. Polar.	Diameter at Mean Distance, Sun—Earth. Equatorial.
	h		"	"	"	"
Oct. 5	10·8	*v*	17·137	17·280	9·394	9·473
	16·0	*h*	17·015	17·501	313	579
7	11·4	*v*	17·351	17·412	376	411
13	11·3	*v*	18·047	18·098	378	405
24	10·6	*v*	18·940	19·170	322	435
Nov. 7	11·8	×	19·319	19·513	338	432
8	14·4	*h*	19·487	19·673	434	524
9	8·0	*v*	19·290	19·553	355	482
14	12·0	×	19·124	19·319	411	507
27	8·0	*v*	17·830	17·791	476	457
	11·3	×	17·598	17·773	365	457
28	7·2	*v*	17·400	17·690	323	479
	11·1	×	17·208	17·641	230	462
	14·0	*h*	17·266	17·487	270	388
29	10·7	×	17·102	17·396	253	412
	13·6	*h*	17·360	17·126	401	275
Dec. 2	13·7	*h*	16·865	16·872	374	376
7	7·2	*v*	16·072	16·299	342	472
				Mean	9·353	9·446
				Mean error	±0·015	±0·016

The measures reduplicated on the same day are made in different positions of the disc relative to the eye of the observer, and may be considered as independent. No systematic discordance occurs between the measurements in the two (or three) directions of the two diameters with the vertical line. For we have

[redacted]

Polar Diameter.			Equatorial Diameter.		
v	h	x	v	h	x
9″·394	9″·313	9″·338	9″·579	9″·473	9″·432
·376	·434	·411	·524	·411	·507
·378	·270	·365	·388	·405	·457
·322	·401	·230	·275	·435	·462
·355	·374	·253	·376	·482	·412
·476				·457	
·323				·479	
·342				·472	
9″·371	9″·358	9″·319	9″·428	9″·452	9″·454

$v-h = +0''{\cdot}013$ $\qquad$ $v-h = -0''{\cdot}024$

in both cases the difference between vertical and horizontal direction being smaller than the probable error of it.

The differences "equatorial minus polar" for the three directions are

	$2a-2b$	$\frac{a-b}{a}$
v	$+0''{\cdot}057$	1 : 166
h	$+0{\cdot}094$	1 : 101
×	$+0{\cdot}135$	1 : 70

Hence the figure of the planet, when the axis of rotation is inclined at 45° to the vertical line, seems to the observer to be different from that in the other positions. But the result depends chiefly upon the two measures of the polar diameter made on November 28 and 29, which are the smallest of the whole series. I believe the mean of all the measures to be free from personal errors arising from difference in the position of the rotation axis in regard to the vertical line. Hence we have the difference between the polar and equatorial diameters in mean distance of the Earth from the Sun $=0''{\cdot}093$ with the mean error $\pm 0''{\cdot}021$, and the polar compression $=\frac{1}{102}$, agreeing well with the result obtained with the great Repsold heliometer of the Remeis Observatory, $0''{\cdot}111$, *i.e.* $\frac{1}{85}$. The mean of the measurements of the polar diameter with the latter heliometer on four days, viz. $9''{\cdot}331$ (mean error $\pm\ 0''{\cdot}034$), is also in agreement with the result above, $9''{\cdot}353$ (mean error $\pm 0''{\cdot}015$). The higher power of the Bamberg heliometer just compensates in these measures for the greater apparent diameter of the disc as measured with the Breslau heliometer in the opposition of 1879. The value $0''{\cdot}1$ for the difference between the polar and equatorial diameter of *Mars* in mean distance of Earth from Sun is doubtless not far from the truth.

1899 *May*.

Observations of Mars made at Mr. Crossley's Observatory, Bermerside, Halifax, during the Opposition 1898–9. By J. Gledhill.

I.

Notes on the Markings Seen on the Disc.

The following observations of *Mars* were made with the 9 inch Cooke Equatorial Refractor (the new triple object glass). The powers used were 240 and 330; the former as that most generally useful, the latter on the very few exceptionally good nights. The planet was carefully examined—indeed, watched almost continuously, often for several hours—on every clear night from 1898 December 19 to the end of March 1899, in all some forty nights. The definition was never continuously good, and the seeing and identification of the features often called for much patient gazing. The limb and the terminator were on every occasion most carefully examined for irregularities of form. No such were ever surely seen except on one night, the one occasion when the perfect stillness of the planet allowed of the use of powers 330 and 470. The southern edge of the N. polar ice-cap was often examined, but no trace of any breaks or projections was ever seen. To a very large extent, no doubt, these failures were simply a measure of the bad observing conditions experienced here during the winter. The projection seen for more than an hour on 1899 January 24 would certainly have escaped detection on an average night owing to the undulations on the limb.

1898 December 19, 11^h to 12^h, λ, the longitude of the central meridian, $=295°$ to $310°$. Bad definition, *p* limb very bright, the bright lune extending inwards up to the Kaiser Sea; *f* limb dull; the N. polar ice-cap large and white. The dusky Delambre Sea extends from the S. edge of the ice-cap nearly to the N. point of the Kaiser Sea. All the region to the east of the Kaiser Sea (between it and the *f* limb) was of a warm tinge.

1898 December 20, 11^h to 12^h, $\lambda=286°$ to $301°$. There was a bright region about the S. pole of the disc—probably Lockyer Land. It was bright and of a pale yellow tint. As always, the N. portion of the Kaiser Sea was the darkest portion of that feature, and also perhaps one of the darkest parts of the disc. There was a little warm colour in the region *p*, the Kaiser Sea (Herschel I. Continent), and a deeper tint in the region following it (Beer Continent). The bright lune at *p* limb was much narrower than on the 19th. Delambre Sea was seen, but not well.

1898 December 22, 11^h, $\lambda=268°$. Lockyer Land, the Kaiser Sea, the grey space between the two, Delambre Sea and the coloured continents of Herschel I. and Beer, were seen as on the 20th.

The *p* and *f* limbs differed very little in brightness: the colour did not run quite up to the *p* limb as it did to the *f* limb. The bright lune on the *p* limb was narrow. At 12^{h}, $\lambda = 283^{\circ}$, the Kaiser Sea was about central. The dark fringe on the S. edge of the N. ice-cap was seen, but not clearly. The *p* limb was perhaps not quite so bright as the *f* limb. At 13^{h}, $\lambda = 297^{\circ}$, the Delambre Sea was better seen. Lockyer Land was bright. At 14^{h} Nasmyth Inlet and Laplace Land were seen, as well as Herschel Strait and Phillips Island.

1898 December 24, 11^{h}, $\lambda = 250^{\circ}$. The Kaiser Sea was not far from the *f* limb; the deepest colour lay to the west of it (Herschel I. Continent), a paler tint between it and the *f* limb. The *p* limb was thought to be less bright than the *f* limb. A faint marking was seen on Herschel I. Continent a little to the E. and S. of Fontana Land. Delambre Sea was seen.

1898 December 27, 12^{h}, $\lambda = 238^{\circ}$. Again the *f* limb was thought brighter than the *p*. All other features as on the 24th.

1899 January 4, 11^{h}, $\lambda = 153^{\circ}$. The only feature seen in the N. portion of the disc was Oudeman Sea. The bright region round the S. pole of the disc was probably Webb Land. Of the E. and W. limbs the *p* was the brighter. Of course Maraldi Sea was seen, but the definition was not good enough to show Trouvelot Bay and Noble Cape.

1899 January 11, 8^{h}, $\lambda = 48^{\circ}$. With the exception of the grey band about the S. pole of the disc (the De Tottingnez Sea &c.) the only marking seen was Airy Sea with a portion of Campani Sea to the N. of it. The bright lune of the *p* limb was wide.

1899 January 13, 7^{h}, $\lambda = 16^{\circ}$. Knobel Sea, the bright Mädler Continent, the grey De la Rue Ocean and the bright Jacob Land near the S. edge of the disc were well seen. The bright lune of the *p* limb was very bright and extended far inwards, say one fifth or one-sixth of the radius of Mars. There was also a considerable brightening of the warm-toned area to the east of the central meridian and near the *f* limb. That portion of Campani Sea just N. of Knobel Sea was darker than the latter, and it was in contact with the ice-cap. Burton Bay was seen.

1899 January 19, 7^{h}, $\lambda = 323^{\circ}$. The Kaiser Sea was not far from the *p* limb; there was no warm colour between it and that limb. There was a faint warm tinge along the *f* limb, and the bright lune on the *p* limb was a well-marked feature. Dawes Forked Bay was seen, but not Burton Bay. Delambre Sea lay along the S. edge of the ice-cap and was darkest opposite the Kaiser Sea. At 8^{h} the Kaiser Sea was much fainter, being near the *p* limb. The darkest feature of the disc was Herschel II. Strait and the two forks. Phillips Land, Arago Strait, Knobel Sea, Kunowski Land, and Jacob Land were seen at 9^{h}. The Kaiser Sea remained faintly visible when it seemed (*i.e.* the eastern boundary of it) but a line close to the *p* limb. Nasmyth

Inlet and Lassell Sea were never seen except when the observing conditions were good.

1899 January 24, 7^h, $\lambda=280°$. The Kaiser Sea was near the central meridian. Delambre Sea was seen. A small bright roughly circular spot was seen close to the western side of the Kaiser Sea near where the equator of Mars cut it. Soft warm colour overspread all the region E. and W. of the Kaiser Sea. The width of the bright lune on the *p* limb was about one-fifth of the radius of the planet. At 9^h Nasmyth Inlet and Lassell Sea were seen: of these two features the portions best seen on all occasions are the hump of the former near the N. point of the Kaiser Sea, and the whole of the southern projection called Lassell Sea. Dawes Forked Bay and Phillips Land were seen.

1899 January 25, 7^h, $\lambda=271°$. The bright lune at the *p* limb, the much less bright terminator, the Kaiser Sea and the ice-cap, all as on the 24th. The Kaiser Sea was central about 8^h. At $8\frac{1}{2}^h$ Lassell Sea was seen occasionally. Dawes Forked Bay was seen, faint and near *f* limb: the two forks or inlets seen as one—*i.e.* definition was not good enough to separate them. Up to 12^h the definition was very poor. Projections &c. on limb and terminator were carefully looked for.

1899 January 31, 10^h. The Kaiser Sea was near the central meridian; the warm colour was deeper to the W. than to the E. of it. Very cloudy night.

1899 February 1, 7^h, $\lambda=209°$. Oudeman Sea was about central; close to its eastern or *f* side was the bright circular region called Fontana Land. The eastern edge of Oudeman Sea was darker than the western. At the first glance this sea might be mistaken for the Kaiser Sea: its shape was triangular with the point downwards, *i.e.* to the N. This northern-pointed portion did not appear to be connected with Schröter Sea to the N. of it. The *p* limb was very bright; the terminator very much less bright.

At $8\frac{1}{2}^h$ Delambre Sea was seen near the *f* limb and resting on the ice-cap. At 9^h the Kaiser Sea lay close to the *f* limb, faint, but easily seen; it was of about the same grey tone as the seas about the S. pole of the disc. At 10^h Webb Land and Burckhardt Land were seen as one continuous broad light-coloured region, *i.e.* the narrow portion named Niesten Isthmus was not noticed.

1899 February 14, 5^h. Airy Sea was not far from the *p* limb: it appeared as a dusky region resting on the S. edge of the ice-cap (N.), and a dusky wisp or two were seen in the central portion of the disc. The S. polar region was bright. At 7^h a portion of De la Rue Ocean was near the *p* limb and was the darkest marking of the disc. A very slight dusky fringe lay along the S. edge of the ice-cap: the *p* limb very bright: the terminator dull. This S. edge has been very carefully examined on every fine night, but no projections or irregularities in the curve were seen.

1899 February 16, 7^h, $\lambda=76°$. Airy Sea faint; Campani Sea, to the N. of it, was the darkest feature of the disc. A faint dusky sweep was seen to the S.E. of Airy Sea: it was probably the faint grey region separating the Mädler and Secchi Continents in Green's map. Christie Bay was of course well seen.

1899 February 17, 6^h, $\lambda=52°$. Campani Sea was the darkest marking of the disc; it was very dark. Airy Sea was not so dark, its southern portion being still less dark and extending southwards to the equator of the disc. Christie Bay was dark, and the dusky sweep to the S.E. of Airy Sea was again seen. At 7^h and 8^h Jacob Land was bright and coloured like Secchi Continent.

1899 February 21, 7^h, $\lambda=31°$. The southern boundary of the Polar cap was a dark fine line: on it lay a dark form, Knobel Sea, very dark in its northern portion and growing fainter to the South. A faint sweep of grey was seen to the N.E. of Knobel Sea at the eastern end of Mädler Continent. The preceding end of the broad band (De la Rue Ocean &c.) seemed to stop short suddenly a good way from the *p* limb, while at the terminator this same broad grey band extended quite up to the edge of the visible disc. De la Rue Ocean was not nearly so dark as the Northern part of Knobel Sea and the Campani Sea to the north of that.

1899 February 22, 7^h to 9^h. Knobel Sea, the bright division between it and Campani Sea, Campani Sea, Christie Bay, all seen as on the 21st. The bright Rosse Land was not seen. Hall Land probably seen: *i.e.* a small bright region was seen not far from the S. pole of the disc, which was probably Hall Land.

1899 February 23. Looked carefully for the bright region (see Green's map) called Rosse Land, but did not see it. The three bays, Dawes Forked Bay and Burton Bay, were well seen.

1899 February 24, 7^h to 9^h. The regions seen were the three bays (Dawes and Burton), Knobel Sea, Leverrier Land, Lassell Sea, Phillips Island, Arago Strait, Jacob Land, Hall Island, and the Kaiser Sea.

1899 February 25, 7^h to 8^h. The Kaiser Sea lay near the *p* limb; it became gradually fainter as it neared the limb, and at last broke the bright line of the limb, *i.e.* the very bright line of the limb was less bright at that part than to the north and south of it. Knobel Sea, Leverrier Land, Lassell Sea, Nasmyth Inlet, the three bays, Phillips Land, and Laplace Land were seen. A bright spot was noticed near where Proctor Cape is marked on Green's map. The fringe along the south edge of the polar cap was faint and narrow.

1899 February 26, 7^h to 9^h. The Kaiser Sea was again watched as it approached the bright lune of the *p* limb, and again that portion of the lune was dimmed. The bright Rosse

Land was looked for but was not seen. All the features seen on the 25th were again easily seen. Lassell Sea could be seen continuously. Nasmyth Inlet was seen now and then for a moment: it was darker but smaller than Lassell Sea. Or, it may be said, that the fainter broad inlet between the N. end of Lassell Sea and the N. end of the Kaiser Sea was seen with some difficulty; while the dark protuberance at the *p* end of the inlet was much more easily seen.

1899 February 27, 7^h. The Kaiser Sea, the three bays, Nasmyth Inlet, Lassell Sea, and Knobel Sea, were seen. It was not a good night.

1899 March 1, 7^h to 12^h. The phenomena attending the approach of the Kaiser Sea to the *p* limb were seen as on February 26. The long narrow Nasmyth Inlet and Lassell Sea were steadily seen, also Lockyer Land, Phillips Land, Knobel Sea, and the three bays. Lassell Sea and the protuberance at the *p* end of Nasmyth Inlet were much darker than the intermediate portion (*i.e.* the portion over which stands the name Nasmyth Inlet in Green's map). The same remarks as to objects seen &c. apply to March 2, 7^h to 10^h.

1899 March 2, 9^h. The Kaiser Sea was near the *p* limb, Knobel Sea near the terminator. The Forked Bays, Delambre Sea, and the bright Phillips Land were seen and identified. When the Kaiser Sea reached the bright lune on the *p* limb, the latter was shorn of much of its brightness. At 7^h Lassell Sea and Nasmyth Inlet were seen.

1899 March 15, 7^h to 8^h. Good definition: power 330: some mist. The features seen may be described thus:—A small bright region round the S. pole of the disc, probably Webb Land; the broad, greenish grey band extending from limb to terminator, *i.e.* Maraldi Sea, &c. &c., and which extended quite up to the terminator but became very faint near the *p* limb; the broad (one-fifth to one-fourth of the radius) bright lune along the *p* limb: a dusky form or feature not unlike the Kaiser Sea, *i.e.* a triangular form, point to the north base to the south, detached from the broad band to the south (Maraldi Sea, &c.), identified as Oudeman Sea: to the north again, resting on the south edge of the N. polar ice-cap lay Schroter Sea: Secchi Continent lay to the west, a warm yellow region, and Herschel I. Continent, of a similar tint, lay to the east of the central Oudeman Sea; the small, bright, roundish Fontana Land was seen well. The definite outline, darkness, and general similarity of Oudeman Sea to the Kaiser Sea, and its extreme unlikeness to the region so named on Green's map, made this a very interesting object. On the 16th the same features were seen in the same way as on the 15th.

1899 March 16, 10^h to 11^h. The triangular form like the Kaiser Sea, again well seen. The central portion is the darkest. Its E. and W. edges were well defined. The base or S. side of the triangle faded away into invisibility.

1899 April 16, 8^h, power 330. The features seen were a small, bright, yellow spot at the S. pole of the disc, the broad grey band of seas &c. extending from limb to terminator, the Kaiser Sea near the terminator, the N. polar cap and the dusky Delambre Sea on its southern edge.

1899 April 17; a few minutes after sunset: definition good; powers 330 and 470. That part of the *p* limb which an hour later will be a bright lune is now of a bright warm colour, while the rest of the disc (the great southern band excepted) is of a dull yellow tint. A long grey form lay near the *p* limb; no doubt it was Oudeman Sea. Delambre Sea appeared, as usual, as a grey form resting on the south edge of the N. polar cap, being darkest close to the cap. Fontana Land was not seen.

1899 April 18, 7^h. Oudeman Sea was about midway between the central meridian and the *p* limb. Delambre Sea &c. as on the 17th. At 8^h on the 19th the same features were seen as on the 18th, only a little more westward, *i.e.* nearer the *p* limb.

1899 April 19, 8^h. Oudeman Sea near the *p* limb. Delambre Sea seen.

2.

Note on a Projection Seen on the Terminator.

1899 January 24. Calm, misty, definition good, image of planet quite steady. On every clear night during this opposition of Mars the limb and the terminator were carefully scrutinised for projections, &c. About $9\frac{1}{2}^h$ a small, seemingly round projection was seen on the terminator: it was about as bright as the disc near the terminator and reminded one of a Jovian satellite when in exterior contact. As to diameter, it was perhaps about $0''\cdot5$, and reckoning the position angle from the middle of the outer edge of the N. polar cap it was about $150°$, *i.e.* it was far up towards the S. pole of the disc in the *sf* quadrant. It remained visible for about an hour, and was invisible at 11^h and 12^h. This was the one night of really fine definition out of the forty on which the planet was observed.

In the above notes *east* and *west* are used in the ordinary astronomical (not areographical) sense.

Note on the Constitution of Saturn's "Crape" Ring.
By E. M. Antoniadi.

Some three years ago the idea was suggested by the writer that the phenomena presented by *Saturn's* inner "dark" ring might be explained by assuming the albedo of its particles to be equal, or at any rate comparable to that of the bright rings, in which case the shading marking the projection of this ring on the planet would be merely the shadow cast by that swarm of meteors.*

Before examining the results arrived at by an application of the deductive method to this interpretation, it would be useful to start with a sound notion of the distribution of matter in the "crape" ring. Professor Barnard's observations of the occultation of *Iapetus* in 1889,† and of the physical appearance of the planet in 1894,‡ have shown this ring to be "very thin at its inner edge," and growing "much denser where it joins the bright ring." True, a reversal of these appearances has been often noted with smaller instruments, the "dark" ring showing itself, at the ansæ, brighter towards the globe of *Saturn*. But this effect is evidently of a purely subjective character, the juxtaposition of the bright ring dwarfing to invisibility that part of the "crape" ring lying in its immediate vicinity. Besides, the fact that the "dark" ring is more transparent to the planet's limb towards its inner edge than close to the bright ring is a striking confirmation of its greater rarefaction near *Saturn*.

This point once established, the hypothesis above enunciated leads us to the following conclusions:—

1. Inasmuch as the heliocentric latitude of *Saturn* can attain the value of 2° 30′, the outline of the dusky shadow projected on the globe would not usually be a rigorous continuation of the "nebular" ansæ.

(*a*) Should the Sun be higher above the plane of the ring-

* *Journal of the British Astronomical Association*, vol. vii. pp. 241, 242.
† *Monthly Notices*, vol. l. January 1890.
‡ *Ibid.* vol. lv. May 1895.

system than the Earth, the breadth of the shadow across the planet would shrink along the minor axis.

(*b*) Should the Sun be lower above the same plane than the Earth, the breadth of the shadow would be increased by the additional shadow of the inner edge of the bright ring. But the darkness of this latter shadow, viewed, as it would be, through the thickest (outer) part of the light-scattering swarm, would be considerably attenuated.

2. The real intensity of the "crape" ring's shadow being an inverse function of the Sun's altitude above the plane of the rings, the transparency of the "dark" ring ought to diminish with the closing of the system. For the perspective grouping of the particles would, in this case—

(*a*) Mask more effectively the planet's limb;

(*b*) Whose intensity would be further reduced by the strengthening of the particles' shadow, consequent on their closer apparent grouping.

Now observation confirms both these deductions. With reference to the latter, we find Proctor saying :—"As the ring-system closes up, the distinction between the dark ring and the neighbouring bright ring becomes less marked, the dark ring appears greyish or slate-coloured, the traces of division less distinct (or less frequently to be noticed), while the outline of the planet is either not seen at all through the dark ring, or only seen with difficulty and indistinctly." *

That the first conclusion is also in accordance with experience the writer only recently found out during a visit paid to the Bibliothèque Nationale, Paris. While consulting there the literature on the subject, he came across a statement of Dawes' in the *Monthly Notices* for January 1851, p. 52, running thus :—"I have always † observed that the upper (southern) and more distant portion of the obscure ring is more plainly seen than the corresponding portion on the side nearest to the Earth, and also that the projection of it at its minor axis is considerably narrower than accords with its breadth at the major axis."

The first part of this sentence is a confirmation of Dr. Barnard's results, above alluded to, while the latter half might be accounted for, by the theory we are examining, in the following manner :—At the time of the observations of Dawes—let us say, 1851 January 1—*Saturn* had the following elements :—

Heliocentric latitude (almost at its maximum negative value)	— 2° 29′
Heliocentric longitude	20° 24′
Visible surface of ring system	Southern

* *Old and New Astronomy*, p. 632.

† Dawes having seen the "crape" ring for the first time on 1850 November 29, the word *always* cannot embrace more than a few weeks in the past.

Let MN in the annexed figure be the outline of *Saturn*, O its centre, AB the "crape" ring, supposed to consist of particles at

least as bright as the planet's surface, OE the direction of the Earth, OS that of the Sun at the time of Dawes' observation, the angle EOS being, for the sake of clearness, grossly exaggerated. Then the point A of the "crape" ring casts its shadow on the planet at a_1 (Aa_1 being parallel to SO), B at b_1; the arc a_1b_1 marking the breadth of the projection of the shadow on the globe. But to the observer on the Earth, the point A is projected at a_2 (Aa_2 being parallel to EO), B at b_2; and it will be seen that the shadow ought to appear shrunk along the minor axis, inasmuch as Dawes was seeing shaded, through the gaps separating the particles along AB, the segment $a_1b_2 < a_2b_2$, the arc a_1a_2 suffering no obscuration through the projection on it of particles whose albedo is fully comparable to its own.

Were the "crape" ring to be really a *dark* ring, we ought whenever the heliocentric latitude of *Saturn* is considerable, to be enabled to distinguish the dusky projection from the shadow it would cast on the globe. Such a difference of shade in the band crossing the planet was sought for by the eagle-eyed Dawes in 1852, but in vain. And it is evident that this very failure, which is unaccountable by any idea associated with a dark ring, is a forced corollary of the theory above examined.

In 1884, M. Trouvelot attacked this subject in his valuable paper entitled *Sur la Variabilité des Anneaux de Saturne*, and published in the *Bulletin Astronomique*.* He also thought that the phenomena observed by Dawes and himself could be explained by the "crape" ring's shadow. But the possibility that the albedo of the individual particles of this ring might be identical with that of the bright rings, which is the corner-stone of the writer's interpretation, does not seem to have dawned in M. Trouvelot's mind, for not only does he not make the slightest allusion to this assumption, but furthermore seems unmistakably to espouse

* Numbers for November 1884 and January 1885.

the view that the "crape" ring is really a dark ring, as the following quotation from his paper proves beyond doubt:—"I then attributed," he says, "the phenomenon" (narrowing of the "dark" ring at lesser axis) "to an effect of irradiation of the light of *Saturn's* globe overstepping the material particles composing the border of this ring. Although it might be probable that irradiation must cause a reduction in the diameter of the particles of the ring projected on the globe, I now think, however, that the phenomenon just described results from another cause." As irradiation is capable of affecting the diameter of dark bodies only when put in juxtaposition with a bright one, M. Trouvelot obviously considered the particles of the "crape" ring to be darker than the globe. But then, without irradiation, the segment a_1a_2 in the preceding figure ought to be dark, not bright as the planet, as Dawes actually saw it. And thus M. Trouvelot's interpretation is shown to be in opposition to observation.

Irradiation doubtless affects the breadth of the shadow cast on the globe by the "crape" ring, but to a slight extent only, as the intensity of such shadow is also slight. Inasmuch, however, as the luminosity of the planet is greatest about its centre, waning very rapidly towards the limb, the effect due to irradiation would not be uniform, attaining its maximum at the minor axis, its minimum in the vicinity of the limbs, a circumstance which would tend to exaggerate the apparent concavity of the shadow's outline with regard to the centre of *Saturn*.

Observations of the Satellite of Neptune from Photographs taken at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal*).

A number of photographs of Neptune and his satellite (twenty-two in all) have been obtained since December 23 with the Thompson Equatorial, using either the 26-inch refractor or the 30-inch reflector. From January 26 an occulting shutter immediately in front of the plate has been used to screen the planet during the greater part of the long exposure on the satellite, a series of very short exposures (usually twenty of one second each) being given for Neptune at regular intervals (usually each minute) by lifting the occulting arm. In this way small well-defined images of Neptune in combination with distinct images of the satellite have been obtained, the photographs admitting of very accurate measurement of the position angle and distance of the satellite. The orientation was determined usually by means of a pair of short exposure images of Neptune, the clock being put out of gear for seven or ten seconds between the exposures to give a convenient displacement in R.A.

The earlier photographs from December 23 to January 19, ten in number, taken before the adaptation of the occulting shutter, were found not to admit of such accurate measurement, and they have therefore not been included in the series measured. The measures were made with a position-micrometer (formerly used for the measurement of solar photographs), which has been adapted by Mr. Simms to the measurement of position angles and distances on photographs of this class. The photographs were measured in reversed positions of the plate by each of two observers giving four independent sets of results. The mean values of position angle and distance as measured are given in the following table, the tabular positions being computed from the data given in the "Connaissance des Temps," based on Mr. H. Struve's elements, the eccentricity of the orbit being neglected owing to the uncertainty as to the present position of the periastron.

Positions of Neptune's Satellite measured on Photographs taken with the 26-inch Refractor.

Date.	Exposures.	Position Angle Observed.	Tabular.	Tab.-Obs.	Distance. Observed.	Tabular.	Tab.-Obs.
1899 d h m	m s	°	°	°	"	"	"
Jan. 26 9 40	20, 20	283.43	283.05	−0.38	14.02	14.20	+0.18
Feb. 2 7 37	20, 20	241.13	240.02	−1.11	16.15	16.07	−0.08
17 7 15	17, 20	45.98	46.86	+0.88	14.59	14.51	−0.08
28 9 46	15, 15	72.51	73.87	+1.36	15.82	16.50	+0.68
Mar. 1 8 35	20, 20	30.04	29.71	−0.33	12.42	12.44	+0.02
1 9 44	20, 20	26.13	26.44	+0.31	12.07	12.12	+0.05
2 9 9	20, 20	301.51	300.59	−0.92	11.78	12.01	+0.23
5 8 47	15, 25	118.07	117.38	−0.69	12.08	12.28	+0.20
9 8 44	20, 20	247.40	248.53	+1.13	15.96	16.34	+0.38
10 8 41	25, 20	196.39	195.80	−0.59	10.51	11.21	+0.70
14 8 55	15, 15	284.45	285.68	+1.23	12.89	13.49	+0.60
27 9 24	20, 20	231.13	232.34	+1.21	14.70	14.82	+0.12

All the photographs were taken with the occulting shutter, except those on March 1. The orientation for the photographs on January 26, February 2 and 17 was determined from the tabular places of Neptune and a known star (at a distance of 32′, 37′ and 13′ on the three dates respectively). On the other photographs it was found directly from the two images of Neptune displaced in R.A., as explained above.

The accuracy of the measures may be inferred from the following table, showing the discordances of the four independent sets of measures from the mean. The initials C. D. and P. M. are those of Mr. Davidson and Mr. Melotte, each of whom measured in the direct and reversed positions of the plate.

Satellite of Neptune. Discordances of Measures from Mean.

Date. 1899.	Position Angle. C. D. D.	C. D. R.	P. M. D.	P. M. R.	Mean Discord.	Distance. C. D. D.	C. D. R.	P. M. D.	P. M. R.	Mean Discord.
	°	°	°	°	°	″	″	″	″	″
Jan. 26	+0·1	−0·5	+0·7	−0·3	±·41	+·02	+·06	−·05	−·03	±·04
Feb. 2	+0·1	−0·3	+0·4	−0·2	·27	+·06	−·02	−·09	+·05	·06
17	−0·3	+0·4	−0·2	+0·2	·27	+·11	−·08	−·08	+·04	·08
28	0·0	−0·1	+0·2	−0·1	·11	+·09	−·12	−·15	+·16	·13
Mar. 1	+0·7	−1·6	+0·4	+0·5	·77	+·01	+·09	−·07	−·03	·05
1	−0·1	−0·1	−0·3	+0·4	·22	+·10	−·15	−·18	+·22	·16
2	−0·2	−0·8	−0·1	+1·1	·57	−·07	·00	−·24	+·31	·16
5	−0·8	0·0	−0·3	+1·1	·56	+·13	+·10	−·14	−·13	·13
9	−0·1	+0·1	+0·1	−0·1	·10	−·02	+·04	·00	−·04	·03
10	−0·2	−0·5	+0·6	+0·1	·37	+·36	+·15	−·36	−·15	·26
14	−0·1	+0·1	0·0	0·0	·05	+·37	−·14	−·05	−·18	·19
27	−0·5	+0·1	−0·1	+0·5	±·27	+·16	+·06	−·49	+·26	±·24
					Mean ±·33°					Mean ±·13″

Notes.

Feb. 28, image of planet elongated; Mar. 1, occulting shutter not used; Mar. 2, image of satellite elongated; Mar. 5, satellite ill defined; Mar. 10, satellite within luminosity from Neptune.

Royal Observatory, Greenwich:
1899, *May* 12.

Observations of Swift's Comet, 1899, *made at Grahamstown, South Africa.* By Major L. A. Eddie.

The first news of the discovery of this comet by Swift reached us on March 10, but, owing to the prevailing cloudy skies of this very droughty season, I was unable to make a search for the comet till March 13, when a partial clearance of the sky permitted me to sweep for it. I soon picked it up in the 9¼-inch reflector about 8 o'clock P.M. Cape uniform time. I found it fairly large and bright, of a very undefined outline, but considerably condensed in the centre, though showing no stellar nucleus or defined cometic envelopes. It was very fluffy and extremely ragged, with woolly protuberances on its northern edge, and possessed a faint, but long, straight tail, proceeding from an

arc about one-fifth of its periphery in the direction away from the sun. It shone with a bluish-white light. It was impossible under the unfavourable circumstances to make any exact estimate of its apparent size or length of tail, though this faint appendage could be dimly traced across the field of an eyepiece possessing a field 30′ in diameter.

Friday, March 17. First evening since 13th inst. sufficiently clear of clouds for observation, and still only at intervals. Moon bright. Comet not visible to naked eye. In reflector the nucleus was more condensed than when last observed, and now nearly stellar. Coma very ragged and extended, and could be traced sweeping backwards in the well-known cometic form, and broadening the narrow tail observed on last occasion, which could still be traced for a distance about 30′, while the visible head was about $3\frac{1}{2}'$ across.

Monday, March 20. Moon very bright. No great change perceptible, but cometic matter proceeding from the head, and then bending back and broadening the tail still more noticeably, also a faint northerly extension of tail.

Wednesday, March 22. Nucleus more condensed; now decidedly stellar. Coma very diffuse, but thin. Tail broader, and of a streaky, hair-like structure. Faint supplementary tail, diverging slightly to the north. On examination of nucleus with Espin ocular spectroscope it yielded a faint continuous spectrum crossed by three bright bands, evidently those of hydrocarbon; the central one, in the green, very broad, bright, and fluffy, ragged on both sides, but more so towards the blue; the second in brightness was situated about the greenish-yellow; and the third, a faint one, in the blue. When viewed with the McClean spectroscope, these bands were partially resolved into lines tapering off towards the more refrangible end.

Thursday, March 23. Moon very bright, and sky hazy. Seeing indifferent. The bending back of lateral streamers into tail very noticeable.

Friday, March 24. Observed comet in bright twilight. No apparent change. Nucleus stellar, head bright, tail broad and fairly well seen.

Saturday, March 25. Moon nearly full. Background too bright to examine detail.

Sunday, March 26. Moon full and very brilliant; but, notwithstanding, comet in reflector appeared bright with broad tail.

Monday, March 27. Dense cloud. Picked up comet for a moment only on side of field, then again obscured by cloud. Comet not since seen, being now lost in the twilight. The colour noted on each observation was bluish-white.

Approximate Positions.

	C.U.T. h m	R.A. h m s	S. Decl. ° ′ ″
March 13	8 5	1 22 45	−15 40
17	8 0	1 7	−11 11
20	8 0	0 59 25	8 23 30
22	7 15	0 55 25	6 29 30
23	7 15	0 53 22	5 32 30
24	6 4	0 51 10	4 44
25	6 25	0 49 31	3 54 30
26	6 30	0 41 40	3 5 30

Instrument 9¼-inch reflector by Calver.
Powers 60 and 100.

Grahamstown,
1899 *April* 2.

Notes on the Spectra of γ Cassiopeiæ and o Ceti.
By the Rev. Walter Sidgreaves, S.J.

γ Cassiopeiæ.

The photographs of the spectrum of *γ Cassiopeiæ* obtained at this observatory are distributed over a period of eight years. There are fifty-two plates all told, of which half are by the old 8-inch glass and half by the Perry Memorial Objective of 15 inches aperture. With few exceptions they are all good photographs; but one of exceptional definition, of date 1898 March 7, was selected for the micrometer. From this plate the chart of the spectrum and table of wave-lengths were first constructed. The remaining plates were then examined, and it was found that with the guidance of the better plate nearly all the tabulated details could be traced also in the photographs of inferior definition.

It was not so easy to form a conclusion upon the general spectrum independently of the results of other observers. It might be in general a bright line or a dark line spectrum, but in either case it should be described as composed of hazy and weakly looking lines and bands. That there were some absorptions could hardly be doubted; the blue Hydrogen line H_γ appeared to be clearly resting on an absorption band; the Helium lines 4025 and 4471 and a line in the green 5295 were also absorptions. But for the rest, the condition of H_δ at one end of the spectrum and of the Magnesium group at the other were in favour of bright lines. The Hydrogen line seemed to have no

greater claim to be called bright than many of its neighbours; and in the Magnesium group it was the silver deposit, not an intervening space, which fell to the wave-length 5170, which is the mean of the group. Influenced by these considerations, a table of wave-lengths was made out on the supposition of a bright line spectrum, and compared with the tabulated lines of other stars. It was then seen that many of the *Orion* lines, including all the Helium lines, agreed better with the spaces between the bright lines than with the lines tabulated. Another table was then made out for the lines, on the supposition of an absorption spectrum; but it was found impossible in this operation to avoid tabulating many bright lines, and the result obtained is a mixed spectrum of bright and dark lines.

The General Spectrum.—The complete spectrum of the star is given in tabular form, with the bright lines indicated by the letter *b* written after them; and in a parallel column the absorption lines of γ *Orionis*, as measured on a plate of date 1896 December 28, are entered for comparison. It will be observed that both dark and bright lines of γ *Cassiopeiæ* are fairly well matched by *Orion* lines. An asterisk (*) means that the line is near an *Orion* line not seen in γ *Orionis*. A dagger (†) means that the line is not contained in Pickering's list of *Orion* lines.

The Hydrogen Spectrum. The following figures, collected from the tabulations of the general spectrum, exhibit the Hydrogen spectrum separately, with the character and relative intensities of the lines:—

	H_ϵ	*i*	H_δ	*i*	H_γ	*i*	H_β	*i*
Absorption	3963	6	4095	5	4334	4		
Radiation	3970	0	4101	2	4340	8	4861	10.
Absorption	3976	6	4107	5	4347	4		

The extreme figures in each case indicate, in wave-lengths, the margins of the broad absorption bands. It will be noticed that the intensity assigned to the radiation H_ϵ is zero. This means that the silver deposit is about the same as that of the continuous spectrum, and the line appears by contrast on the broad absorption. H_δ is stronger than the continuous spectrum, and H_γ much more so. All three have the same appearance of a reversal in the centre of a broad absorption line; but H_β is superlatively bright, with only a very weak, if any, absorption background. The radiation or bright lines increase in intensity with increasing wave-length, while the absorptions fall off. The Hydrogen spectrum therefore of γ *Cassiopeiæ* is very closely the same as described by Professor Pickering in the "Harvard College Annals" in 1897,* and differs from Sir Norman Lockyer's photographs only in the appearance of H_β, which on the South Ken-

* XXVIII. i. 100.

sington plates appears superposed on a broad dark band.* And this difference is probably due to the smaller dispersion employed at Stonyhurst. On some plates by greater dispersion the dark H_β is well marked, but not strongly.

That the bright Hydrogen lines are doubles has been shown by Lockyer, Newall, and McClean. They are not represented so either on the map or in the table of wave-lengths, both of which were constructed from a photograph too small to show the separation. On other plates with the greater dispersion of two compound prisms H_γ has the convincing appearance of a double, inasmuch as it appears not stronger at the centre than at the margins of a comparatively broad line; and on one plate the middle of the line is decidedly weaker.

The Helium Spectrum.—In the following table the Helium lines, as published by Runge and Paschen,† are collated with absorption lines in *γ Cassiopeiæ*:—

Helium.		γ Cassiopeiæ.		Helium.		γ Cassiopeiæ.	
λ	*i*	λ	*i*	λ	*i*	λ	*i*
4009	1	4009	5	4438	1		
4026	5	4025	6	4471	6	4471	6
4121	3	4118	3	4713	3	4711	1
4144	2	4144	4	4922	4		
4169	1	4170	3	5016	6		
4388	3	4388	4	5048	2	5048	2

The Bright Lines.—The supposed Magnesium group at 5170 as a bright line group is confirmed by the high temperature Magnesium line at 4481 appearing also as a bright line. This cannot well be taken for the Iron line 4481·6, because it would be the only strong Iron line in the spectrum of the star out of many equally strong lines in the Iron spectrum. Sherman ‡ has the 5170 line at 516·75, which is a nearer match to the head of the Carbon band at 5165 than our line at 5170, but it is quite impossible to reduce the wave-length we have tabulated.

The lines 4518 and 4586 are those noted by Pickering as examples of "bright regions which are not well defined bright bands, . . . but have rather the nature of bright spaces between dark lines." § Our judgment of them is strongly in favour of true bright lines. The longer wave-length of the two is the brightest line in the spectrum after H_γ, and on some plates its appearance suggests that it would resemble H_γ very closely if it were set off on a similar absorption background.

The line at 5020 is the line noted by Pickering at 5023 as the strongest of the bright lines not due to Hydrogen, and he does not speak of bright 5170; on our plates these two lines are of equal bright intensity.

* *Proceedings of the Royal Society*, lvii. 176.
† *Astrophysical Journal*, iii. 10.
‡ *Astr. Nach.* No. 2707.
§ *Harvard College Annals*, XXVIII. i. 101.

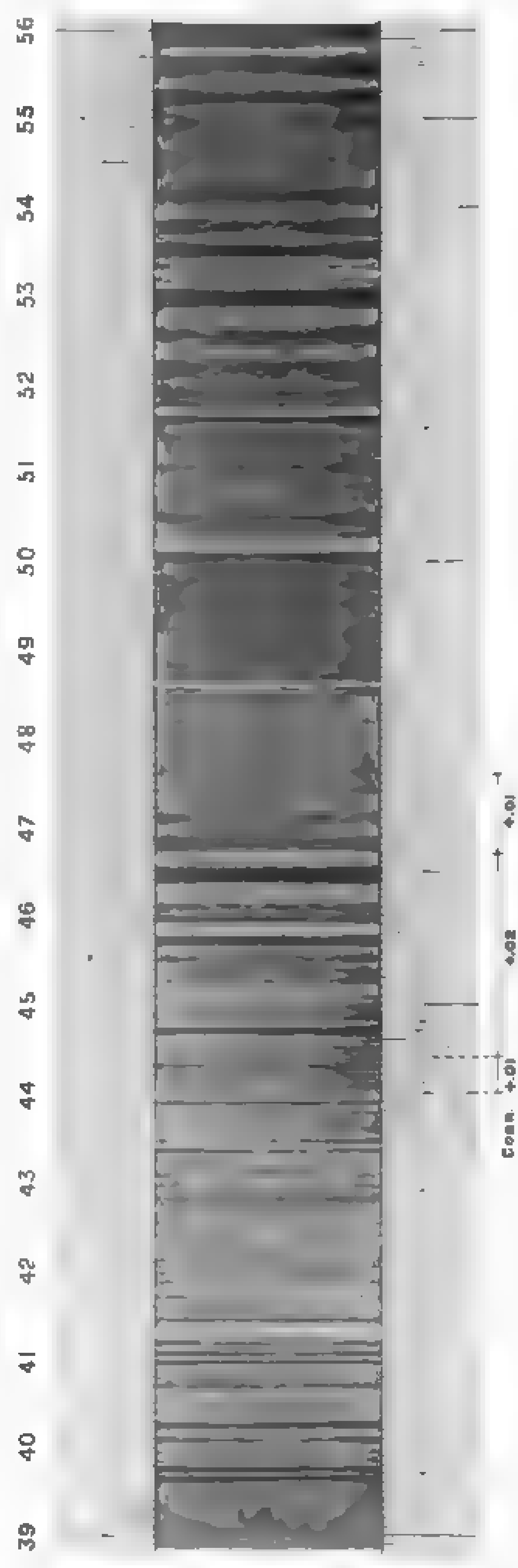
Origins.—Excepting Hydrogen, Helium, and Magnesium, there are no very probable origins assignable. The strongest bright line, already mentioned at 4586, might be attributed to Vanadium, if the stronger lines of the metal made a better figure in the spectrum of the star; but the lines that should be the strongest are the weakest. The following table shows how they are matched in an inverse order of their intensities:—

Bright Lines γ Cassiopeiæ. λ	i	Vanadium (Thalén). λ	i
4382	1	4379·0	10
		4384·1	10
4395	2	4395·1	6
4586	6	4585·1	4

Variability.—The Hydrogen spectrum has shown no signs of alteration during the eight years of observation, but in other parts of the spectrum there is a probability of changes. These in general are not sufficiently pronounced to safeguard our conclusions against erroneous changes, which may be due only to atmospheric effects upon the photographic definition. But the strong bright (Vanadium?) line 4586 appears on several plates with a greater probability of real change. On some plates it is a clear single strong line; on others its appearance is that of a double, too close for separation by small dispersion and of less intensity, with the apparent widening all on the side of shorter wave-length. Real change may account for this line escaping the notice of Sherman at Yale College, and for its appearance on the Harvard College plates as inferior to the line 5023. Our measure of this latter line is 5020, the same as Sherman's dark line 502. Its brightness is noted as varying between 1 and 4, which may be attributed to photographic imperfections, but as a dark line recorded by Sherman, and as a bright line on the photographic plates at Harvard College and Stonyhurst, it claims to be a variable.

The following comparisons with Sherman's lines will serve to show where possible changes may be looked for, bright lines and dark lines being distinguished by the letters *b* and *d*. But the unlettered figure 5275 represents a space between absorption lines:—

Yale.	Stonyhurst.	Yale.	Stonyhurst.	Mean.
399·3 *d*	3995 *d*	530·98 *b*	5275	5296
418 *b*	4177 *b*		5316 *b*	
462·3 *b*	4628 *b*			
467·3 *d*	4681 *d*	542·2 *b*		
492 *d*	4711 *d*			
499 *b*				
502 *d*	5020 *b*	555·75 *b*	5540 *b*	5558
516·75 *b*	5170 *b*		5576 *b*	



SPECTRUM OF γ CASSIOPEIAE, DRAWN FROM A PHOTOGRAPH TAKEN ON MARCH 7, 1898.
STONYHURST COLLEGE OBSERVATORY.

o Ceti.

During the recent period of maximum brightness of *o Ceti* in the autumn of 1898, the weather was far from favourable, and only seven out of thirteen exposures gave good photographic spectra of the star. These are stronger than the photographs obtained in the previous maximum period, owing to the greater magnitude attained in 1898. The spectrum is the same in all its details, with the single exception that the possible bright line at 4862 appears in much stronger contrast than in 1897, and under conditions of defective definition which would then have completely obliterated it. But apart from its position of the H_β radiation, it could not be called a bright line. H_γ and H_δ retain their extraordinary brilliancy, with a possible increase of difference between the two intensities in favour of H_γ.

A wave-length correction which affects the tabulations and chart of the spectrum of *o Ceti*, as given at pages 346–352, vol. lviii. *Monthly Notices*, between λλ 4400 and 4760, has been found necessary. The conclusion was drawn from the comparison columns of γ *Cassiopeiæ* and γ *Orionis*. In both columns the Helium line 4471 appeared at 4469. Six other *Orion* star spectra were then measured, and each gave the line at 4469. But two of these had been also photographed with a two prism dispersion, and these gave the line at 4471. The two-prism wave-length-curve was then carefully re-examined with the aid of Dr. Scheiner's tabulated solar lines in α *Aurigæ* and Rowland's map of the solar spectrum. A large number of these lines were satisfactorily identified on the two-prism photograph of the spectrum of *Arcturus*, and were found, by the curve, to agree with Scheiner's figures to nearly the fifth figure. The shorter, or one-prism curve, was then corrected by the longer one, through the medium of the same star spectra as given by the one-prism and by the two-prism dispersions. The spectra employed were of α *Boötis*, η *Ursæ Majoris*, and α *Cygni*. The resulting corrections* are to the fourth figure—

+1	between	4400	and	4440
+2	„	4440	„	4670
+1	„	4670	„	4760

These corrections, applied to the tabulations of *o Ceti* from the photographs of 1897, improve their relations to the strong metallic

* This correction is applicable to the tabulations of β *Lyræ*, 1895, but not to those of 1893, nor to those of the *Nova*, 1892, which were by another instrument.

lines; and the middle subdivision of the band which begins at λ 446 is brought nearer to the strong Helium line 4471·6.

The Hydrogen Spectrum of o Ceti and of γ Cassiopeiæ.—The bright Hydrogen lines of *γ Cassiopeiæ* seem to exhibit the same character of radiation as that of the electrified Hydrogen tube of the laboratory. In both, the density of the silver deposit upon the photographic plate is greatest by H_β radiation and decreases with the shorter wave-lengths. The two brilliant lines of *o Ceti*, H_γ and H_δ, do not appear to follow the same law, H_δ being far too strong compared with H_γ; but this may be accounted for by the greater strength of the continuous spectrum about H_γ showing less contrast. And this explanation is made more probable by a smaller photograph with a single half-prism, in which the H_γ line is almost lost in the condensed continuous spectrum of its neighbourhood. If we suppose the relative intensities of the lines of *o Ceti* as they appear on the plate without reference to the sensibility curve to be the same as found in the laboratory, it is not easy to imagine the condition of things able to stop out so powerful a radiation as that of H_β. Another query suggests itself: Where is the absorbing atmosphere capable of stopping out H_ϵ, H_β and H_α? Dr. Scheiner's suggestion for *γ Cassiopeiæ*, of a Hydrogen atmosphere great compared with the photosphere of the star, is the only one which seems reasonable, if we limit our thoughts to our present knowledge of spectroscopic phenomena. The explanation fits the observations of *γ Cassiopeiæ* very satisfactorily. The denser Hydrogen near to the photosphere would give the broad dark bands, and the rarefied Hydrogen more remote from the centre would give the bright reversal in the middle. The other lines, bright and dark, would respectively indicate elements *diffused* through the Hydrogen atmosphere, and others *low-lying only*; a supposition well in keeping with the appearance of the lines, which is that of a struggle between radiation and absorption to impress its mark on the plate. But when applied to *o Ceti* the explanation only adds new puzzles to the already perplexing spectrum of the star In this spectrum we have Hydrogen radiation far more intense than in *γ Cassiopeiæ*. We have ink-black broad absorptions, and a brilliant photospheric spectrum. To account for the glowing Hydrogen lines we have to suppose either a far more vast Hydrogen atmosphere or a greatly higher temperature; and for the missing lines we need dense vapours at lower temperatures and co extensive with the Hydrogen atmosphere. It seems preferable to go beyond our laboratory knowledge and suppose an abnormal Hydrogen radiation of a high degree of energy in which some of the oscillation frequencies have fallen out of the spectrum.

γ Cassiopeiæ λ	i	γ Orionis λ	i
3963	6		
3970 *b*	0	3970	10
3976	6		
		3980	1
3983	1	3985	1
3995	2	3995	1
4009	5	4008	7
		4016	2
4025	6	4026	9
		4033	1
*4037	1		
4043	1	4043	1 *d*
		4053	1
		4059	1
4069	3	4068	1
		4072	1
4076	2	4076	1
		4085	1
4088	1	4090	1 *d*
4095	5	4097	2
4101 *b*	2	4101	10
4107	5		
		4111	1
4118	3	4121	5
		4129	2
4131 *b*	3	4131	1
		4135	1
4144	4	4145	7
4155	1	4153	1 *d*
		4162	1
4170	3	4169	1
†4177 *b*	2		
4185	2	4186	1
		4198	1
		4204	1
		4211	1

γ Cassiopeiæ λ	i	γ Orionis λ	i
		4393	1
4395 *b*	2	4399	1
		4409	1
		4418	2
4431	3	4428	1
		4439	2 *d*
†4451	1		
		4457	1 *d*
†4462 *b*	1		
4471	6	4471	6
		4478	1 *d*
4481 *b*	2		
†4485	1		
		4492	1 *d*
		4506	1
4518 *b*	3	4517	1
		4532	1
		4543	1
		4552	2
		4569	2
4573	4 *w*	4579	1
4586 *b*	6 *w*		
*4596	3	4593	1
		4606	1
*4612	3		
		4621	1
4628 *b*	4 *w*	4632	1
4647	6 *w*	4643	2
		4652	2
4664 *b*	4 *w*	4664	1
4681	3 *w*	4678	1 *d*
		4697	2
		4705	1
4711	1	4713	2
		4731	1
		4738	1
		4746	1
		4760	2
		4782	1

γ Cassiopeiæ. λ	i	γ Orionis. λ	i	γ Cassiopeiæ. λ	i	γ Orionis. λ	i
		4225	1			4796	2
†4234 *b*	2					4821	1
4239	1 *d*	4238	1			4839	2 *d*
		4248	1	4861 *b*	10	4861	10
4253	1	4255	1			4871	2
4266	1	4268	3			4885	3
		4275	1			4902	3
4281	2 *w*	4282	1			4923	6
		4289	1	5006	3		
4295	2	4295	1	5020 *b*	4 *d*		
4302 *b*	2	4304	1	5048	2		
4306	2			5104	2		
4317	1	4317	1	5160	3		
		4323	1	5170 *b*	4		
4326	1	4328		5214	3 *w*		
				5256	3 *w*	5254	5
4334	4			5295	4 *w*		
4340 *b*	8	4340	10	5316 *b*	2		
4347	4			5350	4		
		4353	1 *d*	5376	3		
		4364	2	5411	3		
		4374	1	5524	3		
*4382 *b*	1			5540 *b*	2		
4388	4	4388	5	5576 *b*	2		

b = bright line. *w* = wide line. *d* = double line.

The region beyond λ 4923 of γ *Orionis* has not yet been completely mapped.

Stonyhurst College Observatory.

Longitude from Moon Culminations. By D. A. Pio.

(*Communicated by the Secretaries.*)

A. *Theory.*

Purpose of the New Method.—For the determination of longitude on land, especially during journeys through the continents of Africa and Australia, as also on touching an unknown island in the southern seas, the author dares to express his hope that the method put forward in this paper is preferable to the obsolete one of lunar distances.

In the new method the culmination of the Moon serves only to determine exactly, easily, and quickly the precise instant of the Moon's passage through the local meridian. The longitude is deduced from this instant as in the method of Moon's transits. The practical advantage of the new method is that it does not require any transit instruments, and dispenses with the laborious setting of a telescope exactly in the meridian.

The observer is supposed to possess a good sextant furnished with a telescope magnifying at least twice, an artificial horizon, a *well-rated* chronometer, the *Nautical Almanac* for the current year, a set of nautical and logarithmic tables, and last, but not least, to operate on good solid ground, with an assistant to note down the instants of the different observations.

Remarks on Culminations.—The author would draw the attention of the reader to the sense of the word "culmination" as used in this paper. The author does *not* mean by it that the centre of the celestial body is exactly on the local meridian, but that this body is at its greatest altitude. Whether the greatest altitude coincides or not with the meridian passage is quite another question. The author reminds the reader that only the fixed stars culminate really in the meridian. The Sun, the Moon, and all the planets culminate *out* of the meridian.

"Meridian passage" or "transit" is the word the author uses in this paper instead of "culmination," when he means that the centre of the celestial body is exactly on the meridian.

Principle of the New Method.—The local longitude is found very simply through the right ascension of the Moon at the instant of her transit at the place of observation. This right ascension furnishes the corresponding mean time of Greenwich, and the difference between this time and the mean local time at Moon's transit is the longitude sought, in time. So far, there is nothing new.

In the new method the right ascension is not found directly by observation, but deduced from the mean local time of Moon's meridian passage. For this time converted into sidereal time and added to the right ascension of the mean Sun at his transit

in the place of observation, gives immediately the sought right ascension of the Moon.

The real difficulty, therefore, is to find exactly the mean local time at Moon's transit without using a transit instrument. The culmination of the Moon out of the meridian is substituted for her meridian passage, and the lapse of time between transit and culmination is found by a calculation which the author calls "reduction to the meridian." Thus, the instant of Moon's culmination gives the instant of Moon's transit.

The culmination of the Moon can be observed with a good sextant, and so the heavy transit instrument and the difficult operations required to place the instrument exactly in the meridian are dispensed with. However, the culmination can not be observed directly, and the author deduces the exact instant of meridian passage from the instants at which two equal altitudes of the Moon are taken. The middle time between these two instants is used in the calculation of reduction to the meridian, instead of the precise instant of culmination.

The instant of Moon's meridian passage becomes therefore known when the instants of two equal altitudes are given in mean local time. This local time requires the determination of an hour angle from an altitude of the Sun, for the observer possesses only a chronometer indicating, more or less exactly, mean Greenwich time.

This hour angle can be dispensed with, and all errors consequent upon it can be totally eliminated by simply determining the instant of Sun's culmination in the place of observation. This is done, as above in the case of the Moon, by taking two equal altitudes of the Sun. The middle gives then, by reduction to the meridian, the time of Sun's meridian passage, which must be corrected by the equation of time in order to give the instant of mean noon at the place of observation.

When the instants of Moon's transit and of mean Sun's transit have been deduced by calculation from the instants, as given by the chronometer, of the equal altitudes both of Sun and Moon, the mean local time of Moon's transit is given by subtraction.

The novelty in the new method consists, therefore, in the use of the method of equal altitudes. This use renders unnecessary the determination of the meridian's position, the employment of complicated instruments, the observation of Moon culminating stars, and the calculation of hour angles. The arcs measured with the sextant are not used at all in the calculation. All is reduced to the indications of the chronometer.

The practical difficulty in this method consists only in the perfect determination of the instants at which the different equal altitudes are taken.

How to Make the Observations Precise.—In order to obtain the longitude with accuracy the lapse of time between Sun's

transit and Moon's transit must be correct down to the tenth of a second, as even this small fraction corresponds to a mean error in longitude of two-thirds of a minute (of arc). The first requirement is, therefore, that the rate of the chronometer be as uniform as possible, and that its daily amount be ascertained with the greatest precision. In consequence the two culminations of the Sun and the Moon ought to be as near to each other as possible, and to be chosen so that the interval between them be *never* more than twelve hours.

The instants of the different observations must be given to tenths of seconds, which can be done very easily by the chronograph. However, the difficulty is not in noting down the instant of observation, but in catching the precise instant at which the Sun or Moon is *exactly* at the altitude indicated by the graduation. In order to facilitate this the observation must be made with the artificial horizon, and the telescope of the sextant must have a certain magnifying power—say, about five. In this way the contact of the direct image with the reflected one can be observed with more distinctness, and the real instant of contact is perceived with fewer chances of error.

Every error in the instant of observation will influence the middle time deduced therefrom, and in order to give to these times a greater degree of exactness four pairs of equal altitudes must be taken for the Sun and as many for the Moon. The mean of the four middle times for the Sun (or the Moon) may be trustworthy.

Besides, the altitudes of both Sun and Moon must be such that a perceptible change in altitude takes place in so small an interval of time as a tenth of a second. Therefore, the altitudes must be low, but not so much that variations in refraction may make unequal altitudes appear equal.

For this reason the new method cannot be used with great success in high latitudes.

Reduction to the Meridian.—The lapse of time between meridian passage and middle time is given by a well-known formula, which all treatises on nautical astronomy bring under the head 'time from equal altitudes.' The author uses this formula under the following form :

$$x'' = + \frac{\delta_1'' - \delta_2''}{2 \sin H} \left\{ \cot \frac{\delta_1 + \delta_2}{2} . \cos H - \tan \lambda \right\},$$

where x'' is the angle in seconds at the pole between the meridian and that circle of declination which bisects the angle 2H ;

2H the angle at the pole between the circle of declination of the Sun or the Moon at the first observation, and that of the same celestial body at the second observation ;

δ_1 the polar distance from the elevated pole of the observed celestial body at first observation ;

δ_2 the polar distance of the same body at second observation ;
λ the latitude of the place of observation ;
$\delta_1'' - \delta_2''$ is the difference in seconds between the polar distances.

The angle x'' must now be divided either by 15″ in the case of the Sun, or by $15''\cdot0411 - \frac{\Delta^s}{40}$ in the case of the Moon, in order to give the lapse of time between meridian passage and middle time. The symbol Δ^s stands for the variation in 10^m of the Moon's right ascension, as given by the *Nautical Almanac* for the Greenwich time at Moon's transit.

The difference $\frac{\delta_1'' - \delta_2''}{2}$ must be calculated with the greatest precision, as any error in it has an influence on the right ascension of the Moon from which the longitude is obtained.

The angle 2 H is deduced from the interval of time between the observations of the two equal altitudes. 2 H = this interval in seconds, multiplied by 15″ in the case of the Sun, or multiplied by $15''\cdot0411 - \frac{\Delta^s}{40}$ in the case of the Moon.

Error in Longitude.—As the variation in 10^m of Moon's right ascension oscillates from 17^s to 29^s, the error in longitude corresponding to one second of right ascension oscillates from $\frac{150'}{17} = 8'\cdot8$ to $\frac{150'}{29} = 5'\cdot2$, the mean being 7′. The sources of error are :

1. Wrong middle time, arising from want of correspondence between the altitudes measured by the sextant and the indications of the chronometer.
2. Wrong reduction to the meridian arising from wrong values of latitude and polar distances being used in the calculation.
3. Wrong lapse of time between the transit of the Sun and that of the Moon, arising from wrong value of chronometer's daily rate.

The author makes thereon the following remarks :

To 1. The use of four pairs of equal altitudes combined with the employment of the artificial horizon and the magnifying power of five renders the mean of the middle times exact to one-tenth of a second at least.

To. 2. When the quantity $\frac{\delta_1'' - \delta_2''}{2}$ is calculated exactly, and that can always be done, the wrong values of latitude and of the polar distances have no influence on the reduction to the meridian.

To 3. Nowadays chronometers are so well constructed that the changes in the daily rate are insignificant ; besides, the influence of temperature is now taken into account.

[redacted]

Therefore the author hopes that the error in longitude by the new method will amount only to a few minutes of arc in unfavourable circumstances.

Longitude by the Sun.—As in the new method the instant of the mean Sun's transit at the place of observation is given in mean Greenwich time, the local longitude in time is evidently the difference between 12^h and this Greenwich time.

Therefore the longitude is furnished by the new method in two different ways:

1. Longitude by the Sun, deduced directly from the chronometer;
2. Longitude by the Moon, deduced from her right ascension.

Comparison of the new method with the known ones.—The author has occupied himself during many years with finding out a new method for the determination of longitude and tried many contrivances of his own. He has come to the following conclusions:

1. On sea the *best* method is to determine longitude by the chronometer compared with local time deduced from altitudes of the Sun.
2. On sea the method of lunar distances is still the *best* when one wishes absolutely to use the Moon for determining the longitude on board a ship. All methods proposed to supersede Borda's one are inferior to it, and it is lost time and wasted ingenuity to devise such new methods.
3. On sea Borda's method cannot compete with longitude by chronometer, especially now that chronometers have so much improved.
4. On land the telegraph is unsurpassable in its accuracy for the purpose of determining longitudes.
5. On land the method of deducing the right ascension of the Moon from comparison with moon-culminating stars comes the next after the telegraphic method. Its inconveniences consist:

    1. In the necessity of determining accurately the local meridian.
    2. In the use of heavy instruments.
    3. The delicacy of the observations, and the many corrections required.

6. The new method requires no meridian, may be used very easily and everywhere on land, and rests on the indications of the chronometer only. The measurements with the sextant are only used to fix the instants of the observations. The new method is properly a chronometrical method.

7. On land the longitude by the Sun, as determined by the new method from equal altitudes of the Sun, is, when a well-rated chronometer is used, the simplest of all methods after the telegraphic one.
8. The longitude by the Moon, according to the new method, is a good check on the chronometer.

B. *Practice.*

Directions for the observer.—(1). Do not use this method when your latitude exceeds sixty degrees north or south. (2) Determine your latitude with the greatest precision by the artificial horizon, if possible, by the means of different observations. (3) Choose such a day that the Moon's daily variation in right ascension be as great as possible. (4) With the best assumed longitude calculate the approximate Greenwich time of Moon's meridian transit. (5) Before culmination take four altitudes of the Moon in succession, from three to three minutes, and as many corresponding ones after culmination. (6) The observed altitudes of the Moon must not be less than thirty degrees, nor more than sixty. (7) The time of taking the altitudes of the Moon must not be less than one hour and a half before and after culmination, nor more than two hours before and after it. (8) For the *nearest* Sun's meridian transit take four successive altitudes of the Sun before noon, as near the prime vertical as possible, and as many corresponding ones after noon. (9) All altitudes must be taken with the artificial horizon. (10) The instant of every observation must be taken with a chronograph to tenths of seconds.

Rules for the calculations. (1) First calculate longitude by the Sun, then longitude by the Moon. (NOTE These two calculations are to be effected in the same manner, except where the rules expressly indicate the contrary.) (2) Calculate the mean time of the four observations before culmination and that of the corresponding ones after culmination. From these two means deduce the middle time. (3) Find the difference between these two means and convert it into seconds. In the case of the Sun multiply the half of the found number of seconds by 15 and call the result H. (3 *bis*) In the case of the Moon find first in the *Nautical Almanac* the variation in 10^m of the Moon's right ascension for the hour of middle time, divide this number by 40 and subtract the quotient from $15''\cdot0411$ The result is the factor of the half difference between the means. (4) Calculate (down to tenths of seconds) the polar distance from the elevated pole of the Sun (or Moon) for the instant given by the mean of the observations *before* culmination and call it ζ_1. (5) Calculate (down to tenths of seconds) the polar distance from the elevated pole of the Sun (or Moon) for the instant given by the mean of

the observations *after* culmination and call it δ_2. (6) Take the half *sum* of these two polar distances and call the result $\frac{\delta_1+\delta_2}{2}$. (7) Take the half *difference* of these two polar distances, express the result in seconds, and call it $\frac{\delta_1''-\delta_2''}{2}$. (NOTE I.—In the case of the Moon it is necessary to verify the amount $\frac{\delta_1''-\delta_2''}{2}$ by calculating separately the variation of Moon's declination during the interval of time elapsing from the mean instant of the observations before culmination to the mean instant of the observations after culmination. NOTE II.—Particular attention must be paid to the *sign* of $\frac{\delta_1''-\delta_2''}{2}$.) (8) For longitude by the Sun calculate the equation of time for the instant of Sun's transit at the place of observation, with the help of the longitude by account. (9) Calculate the reduction to the meridian by the rules in Article 11 and pay particular attention to the *sign* of the result. (10) To the middle time, as found by Rule 2, apply the above reduction to the meridian with its *proper* sign. (NOTE—In the case of the Sun apply also the equation of time with its *proper* sign.) (11) For longitude by the Sun call the result 'Greenwich time of mean Sun's transit,' and find the difference between it and 12^h. This difference is the sought longitude. (12) For longitude by the Moon call the sum of middle time and reduction to the meridian 'Greenwich time of Moon's transit,' and find the difference between it and that of mean Sun's transit. The result is the mean local time of Moon's transit. Mark whether it is a.m. or p.m. (13) Convert the local time of Moon's transit into the equivalent sidereal time (down to hundredths of seconds) and call the result 'Moon's difference in right ascension.' (14) Calculate (down to hundredths of seconds) the right ascension of the mean Sun at the Greenwich time of mean Sun's transit in the place of observation. (15) To this right ascension of the mean Sun *add* the sidereal time calculated by Rule 13, if the local time of Moon's transit is p.m.; *subtract* this sidereal time from the above said right ascension of the mean Sun when the said local time is a.m. The result is the Moon's right ascension at the instant of Moon's transit. (16) Calculate (with the help of the *Nautical Almanac*) the Greenwich time corresponding to this right ascension of the Moon. The difference between this Greenwich time and the local time of Moon's transit is the sought longitude in time.

Rules for reduction to the meridian.—(1) Take the logarithm of cosine H, that of cotangent $\frac{\delta_1+\delta_2}{2}$, add them, and find the *number* corresponding to the sum. If $\frac{\delta_1+\delta_2}{2}$ is less than 90° this number is positive; if it is more than 90°, negative.

(2) From this number subtract *algebraically* the *natural* tangent of latitude and give to the result its *proper* sign. (3) Take the logarithm of this result, that of $\frac{e_1'' - e_2''}{2}$ as expressed in seconds, the arithmetical complement of sine H and the arithmetical complement of 15″ for the Sun, or that of $15''0411 - \frac{\Delta^s}{40}$ for the Moon, add all together and find the *number* corresponding to the sum. This number is the reduction to the meridian in seconds of time. Pay particular attention to its time. (NOTE I.—It is good to write the words 'positive' or 'negative' opposite the different numbers entering into this calculation. NOTE II.—For the Sun *four* decimal places are sufficient for the abovesaid logarithms. For the Moon *five* decimals are necessary.)

Example.

1885 March 27, in a place on the island of Syra, situated exactly in latitude 37° 25′ 30″ N., but in longitude by account 25° E., the following observations were taken with the artificial horizon:

	Measured Heights.	Instants of Observation.
	° ′ ″	h m s
1 Sun's L.L.	78 36 0 ...	7 34 50·9 a.m.
2. „	78 36 0 .	0 55 10·7 p.m.
3. Moon's L.L.	107 44 20	6 34 33·4 p.m.
4. „ .	107 44 20	9 37 36·2 p.m.

The above times are in Greenwich time, as given by a chronometer whose indications have been corrected for error and daily rate.

	h m s		° ′ ″
Middle time .	10 15 0·8 a.m.		
Half difference (– H)	2 40 9·9	–	40 2 28·5
Polar distance of Sun at first observation (– δ_1)		–	87 17 39·2
Polar distance of sun at second observation (= δ_2)		=	87 12 26·5
$\frac{\delta_1 + \delta_2}{2}$		=	87 15 02·9
$\frac{\delta_1 - \delta_2}{2}$		=	2 36·35

Reduction to the meridian calculated by above formula ... . = – 11s 8

	h m s
Middle time	10 15 00·8 a.m.
Reduction to the meridian	−11·8
Equation of time	5 23·0
Greenwich time of mean Sun transit	10 20 12·0 a.m.
Local time	12 0 0·0
Difference	−1 39 48
	° ′ ″
Longitude of Syra by the Sun	24 57 0·0

Calculation of Longitude by the Moon.

I. *Preliminary Calculations.*

	h m s
Time of Moon's first observation	6 34 33·4 p.m.
Time of Moon's second observation	9 37 36·2 „

				° ′ ″
Middle time	=	h m s 8 06 04·8 p.m.		
Half difference	=	1 31 31·4	=	22 5 8
Polar distance of Moon at first observation ($=\delta_1$)			=	81 27 51·5
Polar distance at second observation ($=\delta_2$)			=	81 57 32·8
$\frac{\delta_1+\delta_2}{2}$			=	81 42 42·2
$\frac{\delta_1-\delta_2}{2}$			=	−14 50·65

Reduction to the meridian calculated by the above formula ... = $1^m\ 43^s{\cdot}14$

	h m s
Middle time	8 6 04·80 p.m.
Reduction to the meridian	1 43·14
Moon's transit in Syra (Greenwich time)	8 7 47·94 p.m.
Mean Sun's transit in Syra „	10 20 12·00 a.m.
Moon's transit in Syra (Syra time)	9 47 35·94 p.m.
Acceleration for $9^h\ 47^m\ 36^s$	1 36·53
Sidereal time at Sun's transit in Syra	20 3·05
Moon's right ascension at transit at Syra	10 9 15·52

II. *Calculation of Longitude.*

Moon's right ascension for March 27, 8^h is ...	10 8 57·88
Change in $7^m\ 50^s{\cdot}4$ is	17·64
Therefore at Greenwich time $8^h\ 07^m\ 50^s{\cdot}4$ the Moon's R.A. is	10 9 15·52

	h	m	s
Moon's transit (Syra time)	9	47	35·9 p.m.
" (Greenwich time)	8	7	50·4 p.m.
Difference	1	39	45·5
Longitude of Syra by Moon	24°	56′	22″·5 E.

Syra, Greece:
1898 November 2.

Errata.

Professor Schur's paper on *The Diameter and Compression of the Planet Mars.*

Page 330, first line of table, mean of h and v, *for* 6″·23 *read* 6″·28.
" 331, third line from bottom, should *read* $2a$, 6·370, $2b$, 6·275, Diff 0·095; $a = \frac{a-b}{a}$, 67

Cape Observations of Nebulæ. Page 339, the paragraph commencing *h* 262 should run on with next paragraph, and *read*—

. . . and is 13′ N. *p h* 2630 = G.C. 838 . . .

Cape Observations of Occultations, page 340, lines 11, 12—

7-in. equatorial, δ lat., *for* − *read* +.
10-in. astrographic telescope, δ lat., *for* + *read* −.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIX. JUNE 9, 1899. No. 9

Professor G. H. DARWIN, M.A., LL.D, F.R.S., President, in the Chair.

Frederick Evan Peach, 161 Stanstead Road, Forest Hill, S.E. was balloted for and duly elected a Fellow of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

W. C. Plummer, The Owens College, Manchester (proposed by William Esson) ; and

Clement Jennings Taylor, Port Elizabeth, Cape Colony (proposed by L. A. Eddie).

Seventy-six presents were announced as having been received since the last meeting, including, amongst others :—

Berlin Observatory, Resultate aus Beobachtungen 1892–97, and Potsdam Observatory, Photographische Himmelskarte, Band 1, presented by the Observatories ; R. Brown, Researches into the origin of the Primitive Constellations of the Greeks, Phœnicians, and Babylonians, presented by Mr. Lynn ; Wilhelm Olbers's Leben und Werke : Neue Reduktion der in 1795 bis 1831 angestellten Beobachtungen von Kometen und kleinen Planeten, presented by Professor Schur.

A further Investigation concerning the Position Error affecting Eye-estimates of Star Magnitudes. By Alexr. W. Roberts.

In No. 6, vol. lvii. of the *Monthly Notices*, I entered upon an investigation dealing with the amount and nature of the position error affecting visual determinations of star magnitudes. The results obtained in that article were based on an examination of the differences between the direct and reverse magnitude determinations of a group of stars surrounding the short period variable Lac. 5861. Since then it has seemed to me an important addition to the investigation to consider only naked-eye estimates of star magnitudes.

Results based on such estimates would be entirely free from the suspicion that the error might possibly be due to instrumental causes. Further, a comparison could be instituted between the results obtained from naked-eye observations (observations made with both eyes) and the results obtained from telescopic observations (one eye only being used); and this comparison would indicate if the amount and character of the variation were the same whether the right or left eye was used in making the observations.

Several groups of stars were available for the proposed investigation; the same conclusion, however, can be arrived at, and more directly, by considering only two stars, instead of several stars, of a group.

North and south of the well known short period variable κ *Pavonis* are two stars of almost equal magnitude, which have been regularly used along with others in the near neighbourhood as comparison stars for κ *Pavonis.*

The two stars and their positions are

	h m s	° ′ ″
ζ Pavonis	18 28 25	−71 31 50 (1875)
λ Pavonis	18 40 38	−62 19 38

It was the constantly changing magnitudes of these two stars, as observations in varying hour angles were made, that first impressed me with the reality of the phenomenon of position error, and the importance of a thorough investigation as to its nature.

As the hour angle of the stars varies, it is evident that their relative position will also vary. Sub-polo, λ *Pavonis* is the lower of the two stars, and it then seems at least half a magnitude brighter than ζ *Pavonis.*

As the stars rise higher and higher this difference in brightness diminishes, until at an altitude of 50° the two stars seem equal in magnitude. As the stars rise to their upper culmination ζ *Pavonis* becomes the brighter, reaching its maximum brightness relative to λ soon after passing the meridian. It then decreases in brightness as its distance below λ *Pavonis* diminishes,

becoming soon after passing its lower culmination, as already said, half a magnitude fainter than λ *Pavonis*.

This states generally the relation of the variation in the brightness of the two stars to their varying relative positions. We are able, however, as in the case of the stars surrounding Lac. 5861, to deal more rigorously with the matter.

It is evident that as ζ *Pavonis* and λ *Pavonis* circle round the heavens they take up relatively the same position to one another as they would if they revolved round a point midway between the stars. Practically, therefore, for the question to be considered, we may regard ζ and λ *Pavonis* as revolving round this point instead of moving round the heavens.

The co-ordinates of this middle point, which we may call O, are

$$\text{R.A. } 18^{h}\ 35^{m}\ 40^{s}\ (1875)$$
$$\text{Dec. } -66^{\circ}\ 56'\ 9''$$

and the angle formed between the line joining the two stars and the line passing through O and the pole is

$$7^{\circ}\ 7'\ 26''.$$

Let m_ζ be the true magnitude of ζ *Pavonis*, then this magnitude will be affected by

(1) *Atmospheric absorption.* The amount of loss due to this cause can be expressed by the quantity k sec z, k being the co-efficient of absorption and z the zenith distance of the star.

(2) *Relative position with regard to O.* It would appear that the simple trigonometrical expression

$$p \cos(\theta - \mathrm{M}),$$

where θ is the parallactic angle of O, satisfies the variation in magnitude due to this cause. A second term

$$q \cos(2\theta - \mathrm{N})$$

was added in the first discussion of the observations, but it was found that the number of unknown quantities then introduced would overburden the equations.

Thus at any instant of time the observed magnitude of ζ *Pavonis* will be

$$m_\zeta + k \sec z_\zeta + p \cos(\theta - \mathrm{M}).$$

Similarly the observed magnitude of λ *Pavonis*, at the same instant, will be

$$m_\lambda + k \sec z_\lambda - p \cos(\theta - \mathrm{M});$$

and the *difference* between the observed magnitudes of the two stars,

$$(m_\zeta - m_\lambda) + k(\sec z_\zeta - \sec z_\lambda) + 2p \cos(\theta + \mathrm{M}).$$

As the difference between the magnitudes may vary continually during the period over which the observations extend, to the above expression a term

$$m' \, (t - 1895)$$

should be added.

Putting,

$$m_\zeta - m_\lambda = x$$
$$\text{Sec } z_\zeta - \text{sec } z_\lambda = s$$
$$2p \cos \text{M} = \alpha$$
$$2p \sin \text{M} = \beta$$

the type of equation of condition connecting the observed magnitudes of ζ and λ *Pavonis* becomes

$$\text{obs. mag. of } \zeta - \text{obs. mag. of } \lambda = x + m' \, (t - 1895) + sk + \alpha \cos \theta + \beta \sin \theta.$$

In the following table are given all the data necessary for the determination of the unknown quantities

$$x, \; m', \; k, \; \alpha, \text{ and } \beta$$

It may be stated that the differences between the observed magnitudes of ζ and λ are not obtained by direct comparison when the amount of difference is as great as $0^{\text{m}}{\cdot}5$, or even less. In this case intermediate magnitudes are used as sequences.

Rot No.	No of Obsns.	$(t-1895)$	$\text{Sec} z_\zeta - \text{Sec} z_\lambda$	Hour Angle of $\odot$.	Par. Angle of $\odot = \theta$.	$\zeta - \lambda$.	Weight.	Computed $\zeta - \lambda$.
				h m	°	m		m
1	2	+0·3	−3·73	13 54	24·2	+0·40	1	+0·37
2	5	0·9	2·05	14 58	37·7	+0·50	2	+0·51
3	17	0·4	1·13	15 55	49·4	+0·48	3	+0·53
4	25	0·6	0·53	16 53	61·6	+0·48	4	+0·51
5	24	0·7	0·22	17 55	74·8	+0·49	4	+0·43
6	30	0·4	−0·04	18 57	88·5	+0·40	4	+0·29
7	23	0·3	+0·04	19 56	102·5	+0·23	4	+0·13
8	12	0·1	0·08	20 58	118·9	−0·23	3	−0·08
9	11	0·3	0·11	21 56	136·1	−0·48	3	−0·30
10	15	1·5	0·13	22 50	154·3	−0·65	3	−0·48
11	13	1·3	0·14	23 56	178·5	−0·66	3	−0·70
12	10	0·9	0·15	0 55	200·4	−0·71	3	0·85
13	8	0·6	0·15	1 53	220·4	−0·75	3	−0·86
14	5	1·0	0·13	2 52	238·4	−0·82	2	−0·85
15	4	1·1	0·10	4 0	256·5	−0·72	2	−0·70
16	6	+0·9	+0·06	4 47	267·8	−0·65	2	−0·55
17	3	−0·1	−0·06	5 58	283·7	−0·50	1	−0·40

The resulting normal equations are—

$$
\begin{array}{llllll}
 & & & & & \text{m} \\
+47{\cdot}00x & +31{\cdot}30m' & -11{\cdot}42k & +\ 9{\cdot}09\alpha & -15{\cdot}74\beta = & -\ 6{\cdot}08 \\
+31{\cdot}30 & +28{\cdot}24 & -\ 5{\cdot}53 & +10{\cdot}12 & -\ 5{\cdot}08 & -\ 8{\cdot}57 \\
-11{\cdot}42 & -\ 5{\cdot}53 & +27{\cdot}83 & +12{\cdot}23 & +\ 9{\cdot}59 & -\ 8{\cdot}43 \\
+\ 9{\cdot}09 & +10{\cdot}12 & +12{\cdot}23 & +17{\cdot}51 & +\ 4{\cdot}36 & -13{\cdot}30 \\
-15{\cdot}74 & -\ 5{\cdot}08 & +\ 9{\cdot}59 & +\ 4{\cdot}36 & +29{\cdot}48 & -12{\cdot}18
\end{array}
$$

which being solved gives

$$
\begin{array}{rl}
 & \text{m} \\
x = & -0{\cdot}14 \\
m' = & +0{\cdot}02 \\
k = & +0{\cdot}07 \\
\alpha = & -0{\cdot}65 \\
\beta = & -0{\cdot}41
\end{array}
$$

and

$$M = 212^\circ\ 30' \text{ or } 32^\circ\ 30'$$

$$2p = +0^{\text{m}}{\cdot}77.$$

Therefore,

Mag. of ζ Pavonis − Mag. of λ Pavonis

$$= 0^{\text{m}}{\cdot}14 + 0^{\text{m}}{\cdot}02\ (t - 1895) + 0^{\text{m}}{\cdot}07(\sec z_\zeta - \sec z_\lambda) + 0^{\text{m}}{\cdot}77 \cos(\theta - 32^\circ\ 30').$$

The values computed from this final equation are given in the last column of the preceding table. It may be objected that the residuals are large: this may be admitted, but that they are so arises, no doubt, from the impossibility of expressing the varying sensitiveness of different portions of the retina in an exact mathematical form.

We may consider now the several results obtained.

(1) *Magnitude of ζ and λ Pavonis.* The magnitude of ζ *Pavonis*, as obtained from observations, is $4^{\text{m}}{\cdot}30$: the value of λ *Pavonis* consequently is $4^{\text{m}}{\cdot}30 - x = 4{\cdot}44$. The U.A. values are 4·20 and 4·30 respectively. The small value of m', $0^{\text{m}}{\cdot}02$, a quantity less than its weight, indicates still further the permanence of the light of both stars.

(2) *Co-efficient of atmospheric absorption.* The value obtained in the present investigation for this important coefficient is

$$+0^{\text{m}}{\cdot}07.$$

It is possible that this value is slightly too small. I am convinced, however, that the value obtained at Harvard from observations made in the years 1886, 1887, and 1888, and the value generally accepted, is too great, at least for these latitudes of dry atmosphere and clear skies.

The Harvard value is

$$+0^{m}\cdot39.^{*}$$

This would mean that a first magnitude star could not be seen on the horizon. Every clear night at this season I can roughly time my watch by the setting of *Sirius*. As the star reaches the horizon, a straight black line against the dark blue beyond, it flickers for a few seconds, then disappears. Sixth magnitude stars have also been discerned at an altitude of 5°.

From considerations such as these, as well as from the definite value obtained in this paper, it is certain that the value of the coefficient of absorption cannot be greater than one-tenth of a magnitude for places with the same atmospheric conditions as Lovedale.

(3) *Amount and character of Position Error.* The expression

$$0^{m}\cdot77 \cos(\theta - 32^\circ\ 30')$$

indicates that the maximum variation due to relative position is reached when the parallactic angle of the centre O is 32° 30′. Now the line joining ζ and λ makes an angle of 7° 7′ with the meridian line: thus the apparent difference between the brightness of ζ and λ *Pavonis* is greatest when the line joining the two stars makes an angle of 25° 23′ with the vertical.

A simple diagram may explain this far more directly and clearly than a literal or trigonometrical statement.

FIG. 1.

FIG. 2.

In Fig. 1 we have the position of λ with respect to ζ when the magnitude of λ with relation to ζ seems at a maximum. In Fig. 2 the magnitude of λ is at a minimum with relation to ζ *Pavonis*.

* *Harvard Annals*, vol. xix. Part 2, p. 252.

In the investigation already referred to at the beginning of this paper (*Monthly Notices*, vol. lvii. April 1897, p. 483) I obtained an angle of 32° with the vertical, as that at which the lower of two stars seemed to reach its maximum brightness.

In this investigation the angle arrived at is 25° 23′. The difference of $6\frac{1}{2}°$ is accounted for by the fact that however great the care taken to keep the position of the head erect, there is always a small inclination when looking through an ordinary theodolite, the instrument used at Lovedale. On the other hand, in naked-eye determinations there is no tendency to any inclination of the head.

Combining both results the following definite conclusions regarding the influence of relative position on apparent magnitude may be accepted :

(1) Through the unequal sensitiveness of the retina the lower of two stars will appear relatively brighter than it actually is.

(2) The maximum increase in relative brightness does not take place when one star is directly under the other, but *after* it has passed the vertical. The angle of maximum variation is about 30°.

(3) The amplitude of relative change due to this cause amounts to no less than three-fourths of a magnitude.

(4) The similarity between the results obtained when both eyes are used, and when only one is used, naturally points to the fact that the error is of the same magnitude and character whichever eye is used.

A simple experiment settled the locus of the error. I had rather inclined to the view that the *seeming* variation was more mental than physiological—that, in fact, the eye saw perfectly enough, but the brain behind, for some reason or another, put its own interpretation on the sensations presented to it.

When the constellation *Pavo* was low down, and when therefore λ seemed about $0^{m}\cdot8$ brighter than ζ, I adopted an exceedingly undignified mode of observation—viz. looking at the constellation with head downwards, my two legs being the window through which the observations were made.

To my thus looking the positions of the stars were the same as they would be if viewed in orthodox fashion : *Pavo* did not seem upside down. The brain had received the picture presented to it, but from association or some other mental sense it turned the impression upside down, thus making the view appear more real.

There was this important difference however, λ *Pavonis was no longer* $0^{m}\cdot8$ *brighter than* ζ*; it was instead over half a magnitude fainter.*

Indeed, all the magnitudes of the stars in the neighbourhood were what they would be after an interval of twelve hours. No more decisive proof could be forthcoming of the cause of

the variation. It was entirely confined to the retina. Further, the phenomenon is in no way restricted to one or two observers. If this were so I would not enter so fully into the matter. Instead of being restricted, I believe it to be a condition of vision.

I have already referred to well-known observers, Barnard, Pickering, and Chandler, who have abundantly testified to its existence, as far as they were concerned. Recently Dr. W. J. S. Lockyer, in his valuable dissertation on the period of *η Aquilæ*, finds that Schmidt's observations are affected by a systematic error depending on the relative position of the variable and its comparison stars.

Indeed, there are few observers who have made the visual determination of star magnitudes a particular line of research who have not been brought face to face with the difficulty.

Lovedale: 1899 May.

Note on the Construction and Use of Réseaux.
By Arthur R. Hinks, M.A.

Very little has been published on the construction and use of *réseaux* since Professor Vogel described in the *Bulletin du Comité Permanent*, vol. i. p. 86, the experiments undertaken by Dr. Scheiner, when, at the inauguration of the Astrographic Chart, the study of the subject was confided to the Potsdam Observatory. A few scattered references show that astronomers engaged on the chart work have generally followed Dr. Scheiner in endeavouring to secure extreme fineness of the photographed image of the *réseau* by the use of very finely ruled *réseaux* placed very nearly in contact with the plate.

Some experiments which I made last year suggest that this procedure may with advantage be modified.

In the first place, it seems doubtful if one should aim at making the image of the *réseau* line as fine as a micrometer wire, unless Professor Turner's form of micrometer is used, in which the point of intersection of the line with a glass scale has to be *estimated*. It is certainly easier to set a wire upon a line well defined, but broader than itself.

Secondly, it is inconvenient to be obliged to place the plate very close behind the *réseau*. The use of commercial plates at any time is then quite out of the question, since they frequently deviate from flatness by several tenths of a millimetre. And even patent plate-glass plates occasionally have sufficient curvature to bring them into contact with and cause damage to the *réseau*.

The lines in the Gautier *réseau*, No. 86, belonging to the Cambridge Observatory, are about $0^{mm}{\cdot}01$ wide. A plate was placed behind this in a tilted position, so that one end was in contact with the *réseau* and the other end separated from it by a measured amount. The definition of the image fell off very rapidly, and with a separation greater than $0^{mm}{\cdot}05$ the lines were fuzzy and the first pair of diffraction bands conspicuous.

Now the distance between the first pair of minima in the diffraction pattern varies directly as the distance between the *réseau* and the plate and inversely as the width of the *réseau* line, and this suggested that a wider line might give a sharper image. I silvered some glass plates and ruled a number of lines of various widths. Exposures on plates tilted behind these experimental *réseaux* showed that the lines about $0^{mm}{\cdot}02$ wide gave on the whole the best results. The definition of the image was scarcely impaired with a separation of $0^{mm}{\cdot}5$, and fell off slowly beyond that.

M. Gautier has, in accordance with this result, made for the Observatory another *réseau*, No. 88, in which the lines were to be $0^{mm}{\cdot}02$ wide. They are actually very slightly narrower than this. But the new *réseau* is a very great improvement on the old one, and we have been able, without damage to the silver film, to impress good images of it on the commercial plates at present used with our five-inch portrait lens. I believe, then, that it will be found that an increase of the width of the ruling to $0^{mm}{\cdot}02$ is of great advantage. It should bring nearer the time when every celestial photograph has a *réseau* impressed on it.

Various methods have been employed for impressing the *réseau* upon the plate, but they nearly all agree in the use of parallel light. The most general practice seems to be to put the *réseau* slide over the object-glass and use a small source of light in the focal plane of the telescope. This is troublesome, and it seems to me to be unnecessary, if not actually disadvantageous. I believe that it would be better to use a small source of light placed at a distance from the *réseau* equal to the focal length of the telescope, without any collimator.

We cannot use a source of light which is practically a point source, because the exposure required is inconveniently long. If we use light coming through a diaphragm of, say, $\frac{1}{4}$-inch aperture, the geometrical divergence of a pencil of light passing through the *réseau* is the same in both cases, and in any case the consequent widening in the image is negligible in comparison with the effects of diffraction.

If we use divergent light, the scale value of the image is altered by a small amount depending upon the separation between *réseau* and plate and the distance of the light source. But this is of no importance whatever. The angular value of the *réseau* interval is quite arbitrary, depending in the first place upon the mean focal length of the objective, which may easily differ from

plate equal to the focal length, t
are approximately the same as t
stars, unless the irregularities i
have thus a method of avoiding
errors due to curvature of the p

My conclusions are, then, th
width of the ruled *réseau* lines
on the plate by light from a sou
at a distance equal to the fo
objective.

Cambridge Observatory:
1899 June 6.

On the formulæ of reduction to th
distances of stars.

The author being unable to re
" Handbook of Professional Instr
Branch, Survey of India Departn
to the observed zenith distance of
with those given by Chauvenet i
Astronomy," 5th ed. vol. ii. pp. 2
was led to an examination of th
that the discrepancies were caus
small terms having been neglecte
expansion for the correction, an
assumed that the correction to
declination is the same as the
zenith distance of the star. At a

esting to examine them and, at the same time, show how to deduce the survey of India formulæ from Chauvenet's.

The instrumental declination δ' is really the difference between the readings on the pole and on the star subtracted from 90°. In practice, however, the reading on the pole cannot be obtained, so that a correction must be computed for it and combined with the correction to the reading on the star. For let

$$z_p = \text{observed reading on pole}$$
$$z_s = \quad " \quad " \quad \text{star}$$

and let Δp, Δs be the corrections to these for instrumental error, so that

$$z_p + \Delta p = \text{true Z.D. of pole}$$
$$z_s + \Delta s = \quad " \quad " \quad \text{star.}$$

Then, in the case of a star north of the zenith,

$$\delta' = 90^\circ - (z_p - z_s)$$
$$\delta = 90^\circ - \{(z_p + \Delta p) - (z_s + \Delta s)\}$$
$$\therefore \delta' - \delta = \Delta p - \Delta s$$
$$\therefore \Delta s = \Delta p - (\delta' - \delta)$$

and, in the case of a star south of the zenith,

$$\Delta' s = (\delta' - \delta) - \Delta p = -\Delta s.$$

Taking the last of Chauvenet's three equations (191), we have

$$\cos\delta\cos(\tau - m) = \cos c\cos\delta'.$$

Put $\delta' = \delta + h$ and expand, then

$$\cos\delta\cos(\tau - m) = \cos c\,(\cos\delta - h\sin\delta)$$

or

$$h = \cot\delta\left\{1 - \frac{\cos(\tau - m)}{\cos c}\right\}.$$

Expanding $\cos(\tau - m)$ and $\cos c$ to two terms,

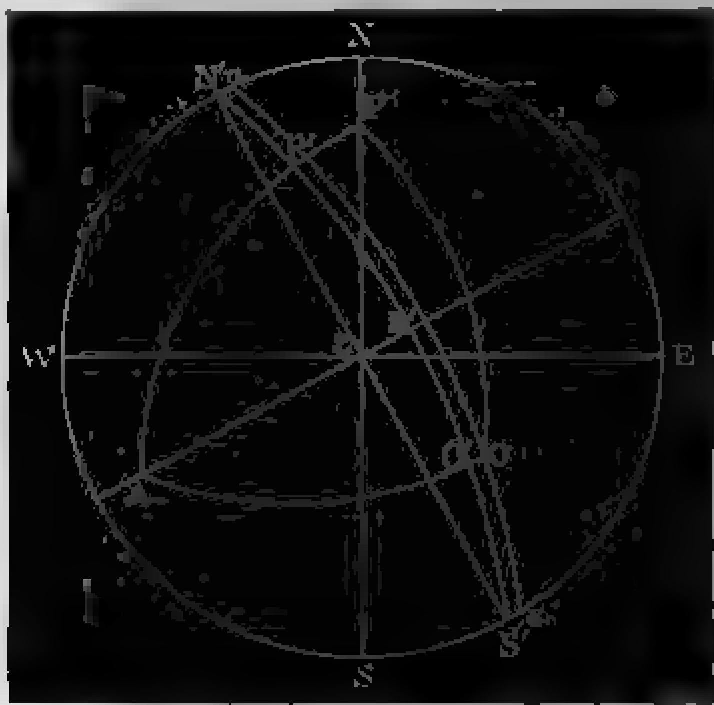
$$h = \delta' - \delta = \frac{\cot\delta}{2}\{(\tau - m)^2 - c^2\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (\text{A})$$

If we insert for c its value $(\tau - m)\cos\delta - n\sin\delta$, this reduces to

$$\delta' - \delta = \frac{\cot\delta}{2}\{(\tau - m)^2 - (\tau - m)^2\cos^2\delta + 2n(\tau - m)\sin\delta\cos\delta - n^2\sin^2\delta\}$$

$$= \frac{(\tau - m)^2}{4}\sin 2\delta + n(\tau - m)\cos^2\delta - \frac{n^2}{4}\sin 2\delta.$$

This differs from the first term of Chauvenet's expansion (193) by the second and third terms, which therefore show the error of that expansion.



Having now found the correct expression for $\delta'-\delta$, it remains to find Δp. Using Chauvenet's Fig. 48, $\Delta p = \mathrm{ZP} - \mathrm{Z'P'}$. By spherical trigonometry, since

$$\mathrm{AP'} = 90^\circ \text{ and } \mathrm{AO'} = 90^\circ$$
$$\cos \mathrm{Z'P'} = \cos \mathrm{PAZ},$$

we also have

$$\mathrm{PA} = 90^\circ - n\,;\ \mathrm{AZ} = 90^\circ - b.$$
$$\therefore \cos \mathrm{ZP} = \sin b \sin n + \cos b \cos n \cos \mathrm{PAZ}$$
$$= \sin b \sin n + \cos b \cos n \cos \mathrm{P'Z'}\,;$$

or expanding and putting $\mathrm{Z'P'} = \mathrm{ZP} - \Delta p$,

$$\cos \mathrm{ZP} = bn + \left(1 - \frac{b^2}{2} - \frac{n^2}{2}\right)(\cos \mathrm{ZP} + \Delta p \sin \mathrm{ZP})$$

but

$$\mathrm{ZP} = 90^\circ - \phi.$$
$$\therefore \sin \phi = bn + \{1 - \tfrac{1}{2}(b^2 + n^2)\}(\sin \phi + \Delta p \cos \phi).$$
$$\therefore \Delta p = \frac{\tan \phi}{2}(b^2 + n^2) - \frac{bn}{\cos \phi} \quad . \quad . \quad . \quad . \quad . \quad . \quad (\mathrm{B})$$
$$\therefore \Delta s = \frac{\tan \phi}{2}(b^2 + n^2) - \frac{bn}{\cos \phi} - \frac{\cot \delta}{2}\{(\tau - m)^2 - c^2\} \quad . \quad . \quad (\mathrm{C})$$

for north stars;

$$= \frac{\cot \delta}{2}\{(\tau - m)^2 - c^2\} + \frac{bn}{\cos \phi} - \frac{\tan \phi}{2}(b^2 + n^2)$$

for south stars.

This is the complete expression for the correction to an observed zenith distance for instrumental error, and by substituting in it the values of a, b, and c, the numerical value will be found.

Correction for Collimation Error c.—Suppose $a=0$ and $b=0$ then

$$n=0 \text{ and } \tau-m=c\sec\delta$$

$$\therefore \Delta s=-\frac{\cot\delta}{2}c^2\frac{(1-\cos^2\delta)}{\cos^2\delta}=-\frac{c^2}{2}\tan\delta$$

for a north star, and $+\frac{1}{2}c^2\tan\delta$ for a south star. Of course, if the star is south of equator δ will be negative, and the sign of the correction will be reversed.

Correction for Azimuthal Deviation.—Put $b=0$ and $c=0$, then

$$n=-a\cos\phi,\ \tau-m=-a\cos\phi\tan\delta$$

$$\Delta s=\frac{\tan\phi}{2}\cdot a^2\cos^2\phi-\frac{\cot\delta}{2}(a^2\cos^2\phi\tan^2\delta)$$

$$=\frac{a^2}{2}(\sin\phi\cos\phi-\cos^2\phi\tan\delta)$$

$$=\frac{a^2\cos\phi\sin(\phi-\delta)}{2\cos\delta}$$

$$=-\frac{a^2\cos\phi\sin z}{2\cos\delta}$$

for both north and south stars.

Correction for Dislevelment of the Transit Axis.—Put $a=0$ and $c=0$, then

$$n=b\sin\phi,\ \tau-m=b\sin\phi\tan\delta,$$

$$\Delta s=\frac{b^2\tan\phi}{2}(1+\sin^2\phi)-\frac{b^2\sin\phi}{\cos\phi}-\frac{\cot\delta}{2}b^2\sin^2\phi\tan^2\delta$$

$$=-\frac{b^2\sin\phi}{2\cos\phi}(1-\sin^2\phi)-\frac{b^2\sin^2\phi\tan\delta}{2}$$

$$=-\frac{b^2\sin\phi}{2\cos\delta}(\cos\phi\cos\delta+\sin\phi\sin\delta)$$

$$=-\frac{b^2\sin\phi\cos(\phi-\delta)}{2\cos\delta}$$

$$=-\frac{b^2\sin\phi\cos z}{2\cos\delta}\text{ for north stars}$$

$$=+\frac{b^2\sin\phi\cos z}{2\cos\delta}\text{ for south stars.}$$

The above formulæ agree with those of the "Survey of India Handbook." They can also be deduced from Mayer's formula for the correction to an observed transit by substituting the

instance,

Collimation Error.—$\tau = c \sec \delta$.

Correction

$$=\frac{c^2}{2}\cot z - \frac{c^2 \sec^2 \delta \cos \phi \cos \delta}{2 \sin z}$$

$$\Delta z = \frac{c^2}{2 \sin z}\left(\cos z - \frac{\cos \phi}{\cos \delta}\right) = \frac{}{2\ s}$$

If the star is N., $\phi = z - \delta$,

$$\Delta z = \frac{c^2}{2 \sin z \cos \delta}(\cos z \cos \delta - c$$

$$= -\frac{c^2 \tan \delta}{2}$$

as before.

Dislevelment Error.—$\tau = b\dfrac{\cos z}{\cos \delta}$.

$$\Delta z = \frac{b^2 \cot z}{2} - \frac{b^2 \cos^2 z}{2 \cos^2 \delta}.$$

$$= \frac{b^2 \cos z}{2 \sin z \cos \delta}(\cos \delta$$

If the star be N., $z = \delta - \phi$ or $\delta = z$ -

$$\Delta z = \frac{b^2 \cos z}{2 \sin z \cos \delta}(\cos z \cos \phi - \sin$$

$$= -\frac{b^2 \sin \phi \cos z}{2 \cos \delta}$$

as before.

The correction for azimuth deviatio stituting

$$\tau = \frac{a \sin (\phi - \delta)}{}$$

may be obtained by combining the formulæ for a, b, and c separately, as the complete expression contains the products of a, b, and c as well as their squares. The following example shows this (it must be remembered that the above expressions are to be multiplied by sin 1″ if a, b, and c are given in seconds of arc):

$$a = +112'', \quad b = +25'', \quad c = +30''$$
$$\phi = +25^\circ, \quad \delta = +35^\circ, \quad z = 10^\circ.$$

Correction for c alone $= -0''.00153$
" " a " $= -0.00584$
" " b " $= -0.00077$

whereas correction for a, b, and c all occurring together $= +0''.0228$, which is three times as great and of opposite sign to the sum of the three corrections taken separately. It must also be remembered that a, b, and c are considered in this formula as being positive when they all tend to make the transit of a south star occur too early.

Taiping, Perak: April 1899.

Small Nebulæ discovered with the Crossley Reflector of the Lick Observatory. By James E. Keeler, D.Sc., Director.

The following small nebulæ were found on two plates exposed with the Crossley reflector, for three and four hours respectively, for the purpose of photographing the spiral nebulæ *M* 51 in *Canes Venatici*. Assuming the position of the nucleus of the great spiral to be R.A. $= 13^h\ 25^m\ 39^s$, Decl. $= +47^\circ\ 42'.6$, as given by Roberts, the positions of the small nebulæ for 1900 are as below:

No.	R.A. h m s	Decl. ° ′	Description.
1	13 23 02	+47 23·3	Round; diam. = 0′·2.
2	24 17	26·5	Spindle-shaped; length = 1′·9.
3	26 05	49·7	Very narrow; length = 0′·6.
4	26 14	45·5	Round; diam. = 0′·2; central condensation.
5	27 07	41·6	Round, diffuse; diam. = 0′·3.
6	27 19	18·3	Round; diam. = 0′·15.
7	27 33	19·8	Slightly elongated; major axis = 0′·2.

No. 2 is long and narrow, with a bright, somewhat irregular axis. No. 3 and No. 4 are close to the great spiral, but apparently not connected with it. The former is recognisable on

the plate in Roberts's collection of photographs, though it is confused with the strongly granular background.

Although these nebulæ are quite conspicuous on the photographs, I found, on examining them with the 36 inch refractor, that all but the brightest are nearly at the limit of visibility with that instrument. Several other faint nebulæ, the positions of which were not noted, were observed during the search. In fact, this region seems to be filled with small, apparently unconnected nebulæ, large numbers of which would doubtless be revealed by long-exposure photographs.

The plates used with the Crossley reflector measure $3\frac{1}{4} \times 4\frac{1}{4}$ inches, giving a field of only about one degree.

Note on the Nebula N.G.C. 6535 (*R.A.* 17^h 59^m, *N.P.D.* 90° 18′). By W. H. Robinson.

(*Communicated by the Radcliffe Observer.*)

This object was picked up with the Barclay Equatorial on May 3, 14^h, when it was fairly conspicuous and about 2′ in diameter. It was also carefully observed with powers 45, 100, and 180 on May 5, 13^h, when "the nebula was rather bright near its centre, with several small stars on the preceding side. The diameter of the nebula was 90″ approximately."

Immediately after my first observation, I identified it in Dr. Dreyer's most useful work, "New General Catalogue of Nebulæ, &c.," and was surprised to find the following description in the column "Summary Description"—viz., "pF, vS," &c., or *pretty faint* and *very small*, &c.

The introduction of the above catalogue contains, p. 12, a progressive scale adopted in Dreyer's work, where *very small* corresponds to 10″ to 12″ diameter, and *pretty large* or *considerably large* would correspond with my estimations.

The nebula was discovered by Hind in 1852, who remarked that it was "*a nebulous object which does not occur in any of the Catalogues of Nebulæ hitherto consulted. . . . It is very small and rather faint, perhaps* 1′ *in diameter* . . ." (*Monthly Notices*, xii. 208).

Although Hind described the nebula as "*very small*," his qualifying note, "*perhaps* 1′ *in diameter*," would place the object with *pretty large* nebulæ on Dreyer's scale.

On looking up the other reference given by Dreyer—viz. Auwers 38—I found, *Konigsberger Beob.* vol. xxxiv. p. 227, Auwers's heliometer observation gave 2′ as the diameter of this nebula. This agrees very closely with the Barclay equatorial observation on 1899 May 3.

I would suggest that the nebula be described as pL instead of vS.

Radcliffe Observatory, Oxford:
1899 June 6.

Ephemerides of Two Situations in the Leonid Stream. By G. Johnstone Stoney, M.A., D.Sc., F.R.S., and A. M. W. Downing, M.A., D.Sc., F.R.S.

The *ortho-Leonids*, the dense part of the great procession, will probably be streaming across the Earth's orbit next November. The Earth will reach the node probably not far from the epoch 1899 November 15^d 18^h (see *Proceedings of the Royal Society*, vol. 64, p. 409). At that time, were it not for moonlight, an endlong photograph of the part of the stream which is near the Earth but outside the atmosphere might perhaps be secured by pointing the telescope along the tangent of the meteoric orbit, which would require it to be pointed towards a situation in the heavens some degrees distant from the radiant point. But as the moon will be nearly full, it seems hopeless to obtain this photograph.

Under these circumstances, and as Dr. Isaac Roberts expressed his willingness to make another attempt to photograph the *Leonids* while outside the Earth's atmosphere, the best course appeared to be to provide an ephemeris which will enable observations to be made on groups of nights upon which the Moon will not interfere, and which come near the date on which the Earth reaches the node. This is done in the subjoined ephemerides. The Earth is so situated on those dates that an actually tangential view of the stream cannot be obtained, and accordingly we had to be content with computing the ephemeris for situations in the stream where it makes a small angle with the line of sight. Two such situations were selected, one to be observed in the group of nights free from moonlight which come next before November 15, and the other to be observed in the group of dark nights following that date. The first of the selected stations is the perihelion of the osculating ellipse of the part of the stream which the Earth encountered in 1866, and the other is the point along the same ellipse of which the mean anomaly is 30°. The osculating ellipse was obtained by allowing for the perturbations since 1866, as calculated in a paper on the perturbations of the *Leonids* read before the Royal Society last March, and published in the *R. S. Proceedings*, vol. 64, p. 403.

The ephemerides have been computed both for the above mentioned points and for points along the ellipse close to them, in order that it may be possible for the observer to foresee the position in his field of view of the tangent to the meteoric orbit. It may be expected that the meteors, if they can be photographed at all, will present themselves as a dim streak,

like the faint part of a comet's tail, crossing the photographic plate in the direction so determined.

An inspection of the ephemerides shows that the direction in which the stream will cross the field of view in the observation to be made on the earlier group of nights is from the *nf* quadrant towards the *sp* quadrant, the position angle being about 50° on October 31, 40° on November 6, and 6° on November 12. In the observations to be made at the end of November and beginning of December, the apparent direction of the stream in the field of view will again be from the *nf* quadrant towards the *sp* quadrant, but the position angle will change but little during this fortnight. It will be between 53° and 55°.

Ephemeris I. records the apparent positions of the perihelion of the above mentioned osculating ellipse from midnight on 1899 October 31 till midnight on November 12.

Ephemeris II. records the apparent positions on the same dates of a point on the ellipse of which the mean anomaly is 0° 1′.

Ephemeris III. records the apparent positions as seen from the Earth at midnight from November 29 till December 11 of that point of the ellipse of which the mean anomaly is 30°.

Ephemeris IV. records the apparent positions on the same dates of a point on the ellipse of which the mean anomaly is 31°.

The computations have been made by Mr. Thomas Wright, of the staff of the *Nautical Almanac* Office, and the expense of the computation has been defrayed out of the Donation Fund of the Royal Society.

Greenwich, Midnight.		Right Ascension. I.	Right Ascension. II.	Declination. I.	Declination. II.
1899.		h m s	h m s	° ′	° ′
October	31	9 41 23	9 43 7	N 18 5	N 18 26
November	1	9 44 10	9 45 54	18 4	18 27
	2	9 47 2	9 48 45	18 5	18 28
	3	9 50 0	9 51 41	18 6	18 30
	4	9 53 5	9 54 43	18 9	18 34
	5	9 56 20	9 57 55	18 13	18 39
	6	9 59 45	10 1 17	18 19	18 46
	7	10 3 23	10 4 51	18 27	18 56
	8	10 7 18	10 8 40	18 38	19 9
	9	10 11 36	10 12 49	18 52	19 25
	10	10 16 23	10 17 23	19 12	19 46
	11	10 21 47	10 22 29	19 37	20 12
	12	10 27 56	10 28 13	N 20 7	N 20 45

Greenwich, Midnight, 1899.		Right Ascension. III.		Declination. III.	IV.
		h m s	h m s	° ′	° ′
November	29	14 15 48	14 17 15	S 7 12	S 7 27
	30	14 16 8	14 17 35	7 13	7 29
December	1	14 16 28	14 17 54	7 14	7 30
	2	14 16 48	14 18 13	7 16	7 31
	3	14 17 7	14 18 32	7 17	7 32
	4	14 17 26	14 18 51	7 18	7 34
	5	14 17 44	14 19 10	7 19	7 35
	6	14 18 3	14 19 28	7 21	7 36
	7	14 18 21	14 19 46	7 22	7 37
	8	14 18 39	14 20 4	7 23	7 38
	9	14 18 57	14 20 22	7 24	7 39
	10	14 19 15	14 20 40	7 25	7 40
	11	14 19 33	14 20 58	S 7 25	S 7 41

Observations of Comet a 1899 (Swift) made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observations were made with the Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power, 55.

Greenwich Mean Solar Time	Observer.	☄ — ✱ R.A.	Corr. for Refraction.	Log. Factor of Parallax.	☄ — ✱ N.P.D.	Corr. for Refraction.	Log. Factor of Parallax.	No. of Comps.	Apparent R.A. of Comet.	Apparent N.P.D. of Comet.	Comp Star.
1899. d h m s		m s	s		′ ″	″			h m s	° ′ ″	
May 6 15 16 25	W.	−0 5·03	−0·02	9·6152	− 9 29·7	−0·1	0·7653	6	23 49 21·69	62 32 12·5	*a*
7 14 47 12	,,	+0 40·42	−0·04	9·6220	−14 29·1	−0·4	0·7781	6	23 45 14·09	61 28 41·0	*b*

Notes.

These observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

May 6.—Comet large and very bright, visible in twilight. Circular, about 5′ in diameter, with a central condensation.

May 7.—There was a well-defined nucleus.

The initial W. is that of Mr. Witchell.

Comparison Stars.

	Star's Name.	Assumed R.A. 1899·0.	Assumed N.P.D. 1899·0.	Authority.
		h m s	° ′ ″	
a	B.D. +27° No. 4640	23 49 25·65	62 41 43·6	Cambridge Astr. Gesell. Catalogue, 14341.
b	79 Pegasi	23 44 32·59	61 43 11·5	Greenwich Ten-Year Catalogue, 1890 (MSS.).

Royal Observatory, Greenwich
1899 June 9.

Equatorial Comparisons of Jupiter, Uranus and Neptune with certain Stars in Newcomb's Standard Catalogue. By John Tebbutt.

The accompanying observations have been made with the 8-inch equatorial refractor and filar-micrometer, and under favourable conditions. In the comparisons of *Jupiter* the first and second limbs were both observed at each transit, and the north and south limbs alternately; in those of *Uranus* the planet's centre was observed on April 18 and May 16, and on each intermediate date the first and north and the second and south limbs alternately; the centre of *Neptune* was observed throughout. In the reduction to the centres the data of the *Nautical Almanac* were employed. The differential co-ordinates have been corrected for refraction and a small error in the perpendicularity of the micrometer threads. The adopted mean places of the comparison stars are the results of an elaborate investigation by Mr. C. J. Merfield, F.R.A.S., from all available catalogues, and are as follows :—

Star.	Epoch.	Mean R.A.	No. of Catalogue.	No. of Obs.	Mean N.P.D.	No. of Catalogue.	No. of Obs.
		h m s			° ′ ″		
η Virginis	1898·0	12 14 41·20	44	1161	90 6 0·0	41	731
ω^1 Scorpii	1898·0	16 0 50·39	18	80	110 23 35·5	18	76
ω^2 Scorpii	1898·0	16 1 25·35	22	118	110 35 36·1	21	108
114 (*o*) Tauri	1899·0	5 21 34·10	25	99	68 8 58·2	23	1

The planet observations are compared respectively with the mean noon ephemeris of *Jupiter* and with the transit ephemerides of *Uranus* and *Neptune* of the *Nautical Almanac*. Weighting the results according to the number of comparisons in each we have the following for the mean corrections to the *Nautical Almanac* :—

		s		″
From Jupiter and η Virginis	ΔR.A. =	+0·09	ΔN.P.D. =	−0·5
„ Uranus and ω^1 Scorpii	„	−0·20	„	+0·8
„ Uranus and ω^2 Scorpii	„	−0·20	„	+0·3
„ Neptune and 114 (*o*) Tauri	„	−0·32	„	+2·6

Windsor Mean Time.	Comps.	Planet's Centre −Star. R.A.	Planet's Centre −Star. N.P.D.	Star Reductions. R.A.	Star Reductions. N.P.D.	Parallax Corrections. R.A.	Parallax Corrections. N.P.D.	Geocentric Ap[…] of Planet's R.A.	
				Jupiter and η Virginis.					
m s		m s	′ ″	s	″	s	″	h m s	
58 27	10	+4 3·42	+11 20·8	+2·94	+19·4	−0·05	+1·1	12 18 47·51	
21 42	10	+3 35·13	+8 19·4	+2·94	+19·4	−0·03	+1·1	12 18 19·24	
3 53	14	+3 9·06	+5 33·2	+2·95	+19·4	−0·07	+1·1	12 17 53·14	
7 40	20	+2 13·37	−0 21·6	+2·95	+19·4	−0·05	+1·1	12 16 57·47	
3 8	20	+1 46·77	−3 10·5	+2·95	+19·4	−0·06	+1·1	12 16 30·86	9
4 32	8	+1 20·39	−5 57·7	+2·95	+19·4	−0·07	+1·1	12 16 4·47	9
1 40	9	+0 54·33	−8 42·4	+2·96	+19·4	−0·08	+1·1	12 15 38·41	8

Uranus and ω¹ Scorpii.

s m s

Date.	Windsor Mean Time.	Comps.	Planet's Centre −Star. R.A.	Planet's Centre −Star. N.P.D.	Star Reductions. R.A.	Star Reductions. N.P.D.	Parallax Corrections. R.A.	Parallax Corrections. N.P.D.	Geocentric Apparent Place of Planet's Centre. R.A.	Geocentric Apparent Place of Planet's Centre. N.P.D.	Corrections to *Nautical Almanac.* R.A.	Corrections to *Nautical Almanac.* N.P.D.
					Uranus and ω¹ Scorpii.							
1898	h m s		m s	′ ″	s	″	s	″	h m s	° ′ ″	s	″
April 18	11 31 20	15	+1 51·69	− 1 31·4	+3·22	+12·6	−0·02	+0·1	16 3 20·24	110 34 17·4	−0·15	+0·2
„ 19	11 13 43	14	+1 43·71	− 1 53·4	+3·24	+12·6	−0·02	+0·2	16 3 12·28	110 33 55·5	−0·17	+0·1
„ 21	11 27 12	10	+1 27·19	− 2 38·4	+3·28	+12·7	−0·02	+0·1	16 2 55·80	110 33 10·5	−0·11	+0·6
„ 27	11 27 10	12	+0 34·51	− 5 3·9	+3·40	+12·9	−0·02	+0·1	16 2 3·24	110 30 45·2	−0·27	+0·1
„ 28	10 15 10	14	+0 25·87	− 5 28·1	+3·43	+12·9	−0·02	+0·2	16 1 54·63	110 30 21·1	−0·21	+0·1
„ 29	10 45 2	14	+0 16·43	− 5 53·7	+3·44	+13·0	−0·02	+0·1	16 1 45·20	110 29 55·5	−0·22	+0·6
May 7	9 36 16	9	−1 0·23	...	+3·59	...	−0·02	...	16 0 28·69	...	−0·19	...
„ 8	9 42 37	20	−1 10·30	...	+3·60	...	−0·02	...	16 0 18·63	...	−0·24	...
„ 13	10 1 44	14	−2 1·20	...	+3·68	...	−0·02	...	15 59 27·81	...	−0·26	...
„ 16	10 4 54	10	−2 32·07	...	+3·73	...	−0·02	...	15 58 56·99	...	−0·15	...
					Neptune and 114 (o) Tauri.							
1899	h m s		m s	′ ″	s	″	s	″	h m s	° ′ ″	s	″
Feb. 22	9 53 9	10	+3 52·90	− 2 53·8	+2·26	− 3·0	+0·01	+0·2	5 25 29·27	68 6 1·6	−0·34	+3·1
„ 23	8 50 0	10	+3 51·68	− 2 55·5	+2·24	− 3·0	+0·01	+0·2	5 25 28·03	68 5 59·9	−0·41	+3·4
„ 24	8 31 55	16	+3 50·69	− 2 58·9	+2·23	− 3·0	+0·01	+0·2	5 25 27·03	68 5 56·5	−0·35	+2·2
„ 25	8 29 43	15	+3 49·85	− 3 0·9	+2·21	− 3·0	+0·01	+0·2	5 25 26·17	68 5 54·5	−0·28	+2·5
„ 27	8 39 52	15	+3 48·39	− 3 6·2	+2·18	− 2·9	+0·01	+0·2	5 25 24·68	68 5 49·3	−0·32	+2·3
„ 28	8 23 50	14	+3 47·97	− 3 8·5	+2·16	− 2·9	+0·01	+0·2	5 25 24·24	68 5 47·0	−0·27	+2·7

Peninsula Observatory, Windsor, N.S. Wales:
1899 *May* 1.

Ephemeris for Physical Observations of the Moon for the Second Half of 1899. By A. C. D. Crommelin.

Greenwich Midnight,	Selenographical Colong. of the Sun	Selenographical Lat. of the Sun	Geocentric Libration Sel. Long. of the Earth	Geocentric Libration Lat. of the Earth	Combined Amount.	Direction.
1899.	°	°	°	°	°	°
July 1	195·76	−0·30	+6·74	−5·71	8·83	229·7
2	208·00	0·33	+6·59	−4·72	8·11	234·4
3	220·24	0·35	+6·15	−3·52	7·07	240·2
4	232·49	0·37	+5·47	−2·17	5·91	248·4
5	244·73	0·40	+4·58	−0·75	4·63	260·7
6	256·98	0·42	+3·52	+0·70	3·59	281·2
7	269·24	−0·44	+2·33	+2·09	3·12	311·9
8	281·49	0·47	+1·05	+3·38	3·55	342·7
9	293·74	0·49	−0·28	+4·52	4·54	3·5
10	305·98	0·51	−1·63	+5·46	5·68	16·6
11	318·22	0·53	−2·95	+6·16	6·84	25·6
12	330·47	0·56	−4·19	+6·61	7·80	32·4
13	342·70	−0·58	−5·31	+6·77	8·60	38·1
14	354·93	0·61	−6·24	+6·63	9·08	43·3
15	7·16	0·63	−6·93	+6·17	9·29	48·3
16	19·38	0·66	−7·30	+5·41	9·05	53·5
17	31·59	0·68	−7·31	+4·33	8·48	59·4
18	43·79	0·71	−6·90	+2·99	7·52	66·6
19	55·99	−0·74	−6·06	+1·42	6·24	76·8
20	68·19	0·76	−4·79	−0·28	4·80	93·3
21	80·37	0·79	−3·15	−2·00	3·72	122·4
22	92·56	0·82	−1·25	−3·61	3·82	160·9
23	104·74	0·85	+0·79	−4·98	5·03	189·0
24	116·93	0·87	+2·78	−5·98	6·58	204·9
25	129·12	−0·89	+4·57	−6·57	8·01	214·8
26	141·32	0·92	+6·03	−6·71	8·99	221·9
27	153·53	0·94	+7·05	−6·44	9·52	227·6
28	165·74	0·96	+7·62	−5·80	9·60	232·7
29	177·96	0·98	+7·74	−4·86	9·13	237·9
30	190·18	0·99	+7·46	−3·69	8·36	243·7
31	202·41	−1·01	+6·84	−2·38	7·25	250·8
Aug. 1	214·65	1·03	+5·94	−0·98	6·00	260·6
2	226·89	−1·04	+4·85	+0·43	4·87	275·1

Greenwich Midnight.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
1899.	°	°	°		°	°
Aug. 3	239·13	−1·06	+3·62	+1·81	4·05	296·6
4	251·38	1·08	+2·31	+3·08	3·85	323·1
5	263·62	1·09	+0·96	+4·25	4·38	347·3
6	275·87	−1·11	−0·38	+5·21	5·23	4·2
7	288·11	1·12	−1·70	+5·95	6·19	16·0
8	300·35	1·14	−2·96	+6·43	7·07	24·7
9	312·59	1·16	−4·13	+6·63	7·82	31·9
10	324·83	1·17	−5·19	+6·54	8·37	38·4
11	337·06	1·19	−6·09	+6·15	8·67	44·7
12	349·29	−1·21	−6·78	+5·47	[illegible]	51·1
13	1·51	1·23	−7·23	+4·50	8·53	58·1
14	13·72	1·25	−7·35	+3·28	8·01	66·0
15	25·93	1·26	−7·09	+1·84	7·30	75·5
16	38·13	1·28	−6·41	+0·25	6·42	87·8
17	50·32	1·30	−5·28	−1·41	5·49	105·0
18	62·50	−1·32	−3·74	−3·01	4·79	128·8
19	74·69	1·33	−1·85	−4·44	4·80	157·4
20	86·87	1·35	+0·25	−5·57	5·58	182·6
21	99·14	1·36	+2·38	−6·30	6·74	200·7
22	111·22	1·38	+4·36	−6·58	7·90	213·5
23	123·40	1·39	+5·99	−6·42	[illegible]	223·0
24	135·59	−1·40	+7·18	−5·85	9·26	230·8
25	147·78	1·41	+7·87	−4·95	9·29	237·8
26	159·98	1·42	+8·04	−3·81	8·92	244·6
27	172·19	1·43	+7·76	−2·51	8·15	252·1
28	184·40	1·43	+7·08	−1·12	7·15	261·0
29	196·62	−1·44	+6·11	+0·29	6·12	272·7
30	208·84	1·44	+4·93	+1·66	5·23	288·6
31	221·07	1·45	+3·62	+2·94	4·67	309·1
Sept. 1	233·29	1·45	+2·26	+4·08	4·65	331·0
2	245·52	−1·46	+0·90	+5·05	5·14	349·9
3	257·76	−1·47	−0·41	+5·80	5·82	4·0
4	269·99	1·47	−1·65	+6·29	6·48	14·7
5	282·23	1·48	−2·79	+6·52	7·11	23·2
6	294·46	1·48	−3·82	+6·45	7·55	30·6
7	306·69	1·49	−4·73	+6·09	7·74	37·8
8	318·92	1·49	−5·50	+5·43	7·70	45·4
9	331·14	−1·50	−6·10	+4·51	7·56	53·6

Greenwich Midnight.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Distance.
1899.						
Sept. 10	343·36°	−1·51°	−6·49°	+3·34°	7·27°	60·8°
11	355·57	1·51	−6·63	+1·98	6·90	75·4
12	7·77	1·52	−6·47	+0·47	6·48	85·8
13	19·97	1·52	−5·94	−1·10	6·06	100·5
14	32·16	1·53	−5·03	−2·65	5·68	117·6
15	44·34	−1·53	−3·73	−4·07	5·53	137·5
16	56·51	1·53	−2·08	−5·24	5·66	158·3
17	68·68	1·54	−0·19	−6·07	6·08	178·2
18	80·84	1·54	+1·80	−6·49	6·75	195·5
19	93·01	1·53	+3·71	−6·45	7·42	209·9
20	105·17	1·53	+5·34	−5·98	8·01	221·8
21	117·34	−1·53	+6·56	−5·13	8·33	232·0
22	129·51	1·52	+7·31	−4·01	8·33	241·3
23	141·69	1·52	+7·55	−2·69	[redacted]	250·4
24	153·87	1·51	+7·33	−1·27	7·40	260·2
25	166·06	1·51	+6·69	+0·17	6·69	271·5
26	178·25	1·50	+5·74	+1·56	5·97	285·0
27	190·45	−1·49	+4·53	+2·86	5·35	302·2
28	202·65	1·48	+3·26	+4·02	5·19	321·0
29	214·86	1·48	+1·91	+5·00	5·35	339·1
30	227·07	1·47	+0·58	+5·76	5·81	354·2
Oct. 1	239·29	1·46	−0·68	+6·28	6·34	6·2
2	251·50	1·45	−1·80	+6·52	6·78	15·4
3	263·72	−1·45	−2·79	+6·47	7·06	23·3
4	275·94	1·44	−3·63	+6·13	7·11	30·6
5	288·16	1·43	−4·30	+5·48	6·96	38·1
6	300·38	1·42	−4·82	+4·56	6·65	46·6
7	312·59	1·42	−5·17	+3·39	6·20	56·7
8	324·80	1·41	−5·36	+2·03	5·74	69·3
9	337·01	−1·40	−5·35	+0·54	5·39	84·2
10	349·20	1·39	−5·11	−1·01	5·21	101·2
11	1·39	1·39	−4·61	−2·53	5·26	118·8
12	13·58	1·38	−3·84	−3·93	5·50	135·7
13	25·75	1·37	−2·77	−5·12	5·85	151·6
14	37·92	1·36	−1·44	−6·00	6·18	166·5
15	50·08	−1·35	+0·08	−6·50	6·50	180·7
16	62·24	1·33	+1·69	−6·57	6·77	194·4
17	74·39	−1·31	+3·24	−6·21	7·02	207·6

Greenwich Midnight. 1899.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
	°	°	°	°	°	°
Oct. 18	86·54	−1·30	+4·59	−5·45	7·14	220·1
19	98·69	1·28	+5·65	−4·37	7·06	232·3
20	110·84	1·26	+6·29	−3·05	6·98	244·1
21	122·99	−1·24	+6·51	−1·59	6·71	256·3
22	135·15	1·22	+6·31	−0·10	6·31	279·1
23	147·31	1·20	+5·72	+1·36	5·89	283·4
24	159·48	1·18	+4·82	+2·73	5·54	299·5
25	171·66	1·16	+3·70	+3·94	5·40	316·8
26	183·84	1·14	+2·44	+4·97	5·52	333·9
27	196·02	−1·12	+1·12	+5·77	5·89	349·0
28	208·21	1·10	−0·17	+6·33	6·33	1·5
29	220·40	1·08	−1·36	+6·62	6·75	11·6
30	232·60	1·06	−2·41	+6·62	7·02	20·0
31	244·80	1·04	−3·27	+6·32	7·11	27·4
Nov. 1	257·00	1·03	−3·91	+5·71	6·91	34·4
2	269·20	−1·01	−4·33	+4·80	6·48	42·1
3	281·41	0·99	−4·53	+3·64	5·80	51·2
4	293·61	0·97	−4·54	+2·26	5·08	63·5
5	305·81	−0·95	−4·35	+0·73	4·39	80·5
6	318·01	−0·94	−3·99	−0·86	4·07	102·2
7	330·20	0·92	−3·46	−2·43	4·22	125·1
8	342·39	0·90	−2·77	−3·87	4·76	144·4
9	354·57	0·88	−1·93	−5·09	5·45	159·2
10	6·74	0·[illegible]5	−0·95	−6·01	6·09	171·0
11	18·91	0·83	+0·14	−6·57	6·57	181·2
12	31·06	−0·81	+1·29	−6·73	6·86	190·8
13	43·21	0·78	+2·43	−6·47	6·92	200·6
14	55·35	0·75	+3·49	−5·91	6·85	210·6
15	67·49	0·73	+4·38	−4·81	6·49	222·3
16	79·63	0·70	+5·03	−3·54	6·14	234·9
17	91·77	0·67	+5·38	−2·09	5·76	248·8
18	103·90	−0·64	+5·41	−0·56	5·44	264·1
19	116·04	0·61	+5·11	+0·96	5·21	280·6
20	128·18	0·59	+4·49	+2·41	5·07	298·2
21	140·33	0·56	+3·61	+3·71	5·16	315·8
22	152·48	0·53	+2·53	+4·82	5·45	332·3
23	164·64	0·50	+1·31	+5·70	5·87	347·1
24	176·80	−0·47	+0·02	+6·34	6·34	359·8

4	298·64	0·22
5	310·84	0·19
6	323·02	−0·17
7	335·20	0·14
8	347·37	0·11
9	359·54	0·08
10	11·69	0·06
11	23·84	−0·03
12	35·98	0·00
13	48·12	+0·04
14	60·25	0·07
15	72·38	0·10
16	84·51	0·13
17	96·64	0·16
18	108·77	0·20
19	120·91	+0·23
20	133·04	0·26
21	145·18	0·29
22	157·33	0·32
23	169·48	0·35
24	181·63	0·37
25	193·79	+0·40
26	205·96	0·42
27	218·13	0·45
28	230·31	0·47

This ephemeris has been constructed for Greenwich midnight instead of noon as heretofore. It is hoped that this change will render its use more convenient to observers in Europe.

The longitudes are reckoned in the plane of the Moon's equator, the axis of reference being the radius which passes through the mean centre of the visible disc. This axis therefore rotates with the Moon, and is not fixed in space.

The inclination of the Moon's equator to the ecliptic is taken as 1°·523, the value used in the *Connaissance des Temps*, that given by the *Nautical Almanac* being 1°·536.

The principal term of the physical libration in longitude has been applied as before, the expression for it being $-0^\circ{\cdot}037 \times$ sine Sun's mean anomaly.

The colongitude of the Sun is 90° (or 450°) *minus* his selenographical longitude. It also is the selenographical longitude of the morning terminator reckoned eastward from the mean centre of the disc. Hence its value is approximately 270°, 0°, 90°, 180° at new Moon, first quarter, full Moon, last quarter respectively. The longitude of the evening terminator is of course 180° greater or less than that of the morning one.

When the geocentric libration in longitude is positive, the region brought into view is on the west limb; when negative, on the east.

When the geocentric libration in latitude is positive, the region brought into view is at the Moon's north pole; when negative, at the south.

The column "Combined Amount" gives the distance between the apparent and mean centres of the disc, and the column "Direction" gives the position angle of the apparent centre from the mean centre, or, which is the same thing, the position angle of the region which is most carried into view by libration. The angles are reckoned eastward from the northern extremity of the Moon's axis.

The terms "East" and "West" are used throughout with reference to our sky, and not as they would appear to an observer on the Moon.

Benvenue, 55 *Ulundi Road, Blackheath, S.E.:*
1899 *June* 10.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY

Vol. LIX. SUPPLEMENTARY NUMBER, 1899. No. 10

Comparisons of the Geocentric Places of Mercury, Venus, Mars, Jupiter, and Saturn, calculated from the Tables of the American Ephemeris Office, with their places calculated from Le Verrier's Tables, for the year 1901. By A. M. W. Downing, M.A., D.Sc., F.R.S.

The geocentric places of the planets named above, with the exception of those of *Mars*, as given in the *Nautical Almanac* for 1901, are calculated from the American Tables: the tables of the Sun, *Mercury*, and *Venus* having been prepared by Professor Newcomb, and those of *Jupiter* and *Saturn* by Mr. G. W. Hill. The corresponding geocentric places in the *Connaissance des Temps* for 1901 are from Le Verrier's Tables. Except for *Mars*, the comparisons have been made by reducing the quantities given in the *Connaissance des Temps* from Paris noon to Greenwich noon; and then finding the differences between the reduced quantities and the corresponding quantities in the *Nautical Almanac*. This is done for intervals of eight days throughout the year, and the results are exhibited in the following tables. For the right ascensions the discordances are given in arc of a great circle, as well as in time, to render them comparable with the discordances in declination.

Correction

Day. 1901.		R.A. Time.	R.A. Arc.	De
		s	"	'
Jan.	2	+·04	+0·5	−0
	10	+·03	+0·4	+0
	18	+·05	+0·7	0
	26	·00	0·0	−0
Feb.	3	−·02	−0·3	−0
	11	−·01	−0·1	−0
	19	·00	0·0	−0·
	27	+·03	+0·5	−0·
March	7	+·03	+0·5	−0·
	15	−·01	−0·1	0·
	23	−·02	−0·3	−0·
	31	−·01	−0·1	+0·1
April	8	−·01	−0·1	+0·
	16	−·01	−0·2	+0·2
	24	−·02	−0·3	+0·1
May	2	−·02	−0·3	−0·1
	10	−·06	−0·9	−0·1
	18	−·08	−1·1	−0·4
	26	−·08	−1·1	−0·3
June	3	−·06	−0·8	0·0
	11	−·05	−0·7	+0·2

VENUS, 1901.

Corrections to Le Verrier's Tables.

Day. 1901.		R.A. Time. s	R.A. Arc. "	Dec. "	Day. 1901.		R.A. Time. s	R.A. Arc. "	Dec. "
Jan.	2	−·04	−0·6	−1·0	July	5	−·09	−1·3	+0·6
	10	−·02	−0·3	−1·1		13	−·07	−1·0	+0·4
	18	−·01	−0·1	−1·1		21	−·08	−1·2	+0·3
	26	·00	0·0	−1·3		29	−·06	−0·9	+0·1
Feb.	3	+·01	+0·1	−1·2	Aug.	6	−·05	−0·7	−0·2
	11	+·01	+0·1	−0·9		14	−·05	−0·8	−0·4
	19	+·01	+0·1	−0·8		22	−·04	−0·6	−0·6
	27	·00	0·0	−0·8		30	−·05	−0·8	−0·7
March	7	·00	0·0	−0·5	Sept.	7	−·05	−0·7	−0·9
	15	−·01	−0·1	−0·5		15	−·05	−0·7	−1·1
	23	−·02	−0·3	−0·5		23	−·05	−0·7	−1·1
	31	−·05	−0·8	−0·2	Oct.	1	−·03	−0·4	−1·2
April	8	−·06	−0·9	0·0		9	−·02	−0·3	−1·1
	16	−·07	−1·0	0·0		17	−·03	−0·4	−1·0
	24	−·09	−1·3	+0·1		25	−·02	−0·3	−0·7
May	2	−·12	−1·7	+0·2	Nov.	2	+·01	+0·1	−0·5
	10	−·12	−1·7	+0·3		10	+·01	+0·1	−0·2
	18	−·12	−1·7	+0·5		18	+·01	+0·1	+0·3
	26	−·13	−1·8	+0·7		26	+·02	+0·3	+0·5
June	3	−·14	−1·9	+0·8	Dec.	4	+·05	+0·7	+0·9
	11	−·10	−1·4	+0·8		12	+·05	+0·7	+1·6
	19	−·11	−1·5	+0·8		20	+·03	+0·4	+2·1
	27	−·10	−1·4	+0·8		28	+·09	+1·3	+2·4

MARS, 1901.

Corrections to Le Verrier's Tables.

Day. 1901.		R.A. Time. s	R.A. Arc. "	Dec. "	Day. 1901.		R.A. Time. s	R.A. Arc. "	Dec. "
Jan.	2	+·03	+0·4	+0·4	Mar.	23	−·02	−0·3	+1·0
	10	+·02	+0·3	+0·6		31	−·05	−0·7	+0·8
	18	+·03	+0·4	+0·5	April	8	−·04	−0·6	+0·8
	26	+·04	+0·6	+0·5		16	−·04	−0·6	+0·7
Feb.	3	+·02	+0·3	+0·7		24	−·04	−0·6	+0·7
	11	+·01	+0·1	+0·7	May	2	−·04	−0·6	+0·6
	19	+·01	+0·1	+0·8		10	−·04	−0·6	+0·5
	27	−·01	−0·1	+0·8		18	−·02	−0·3	+0·4
Mar.	7	−·01	−0·1	+1·0		26	−·03	−0·4	+0·4
	15	−·03	−0·4	+1·0	June	3	−·01	−0·1	+0·3

Day. 1901.		R.A. Time.	R.A. Arc.	Dec.	Day. 1901.		R.A. Time.	R.A. Arc.	Dec.
		s	"	"			s	"	"
June	11	−·02	−0·3	+0·2	Sept.	23	−·03	−0·4	−0·3
	19	−·02	−0·3	0·0	Oct.	1	−·02	−0·3	−0·3
	27	−·02	−0·3	+0·2		9	−·03	−0·4	−0·3
July	5	−·01	−0·2	+0·1		17	−·03	−0·4	−0·3
	13	−·01	−0·2	−0·1		25	−·05	−0·7	−0·3
	21	·00	0·0	−0·1	Nov.	2	−·05	−0·7	−0·3
	29	−·02	−0·3	+0·1		10	−·05	−0·7	−0·4
Aug.	6	−·03	−0·4	−0·1		18	−·04	−0·5	−0·3
	14	+·01	+0·1	−0·2		26	−·05	−0·7	−0·4
	22	·00	0·0	−0·2	Dec.	4	−·05	−0·7	−0·5
	30	−·01	−0·1	−0·1		12	−·06	−0·8	−0·4
Sept.	7	−·01	−0·1	−0·3		20	−·04	−0·6	−0·6
	15	−·02	−0·3	−0·4		28	−·04	−0·6	−0·5

Jupiter, 1901.

Corrections to Le Verrier's Tables.

Day. 1901.		R.A. Time.	R.A. Arc.	Dec.	Day. 1901.		R.A. Time.	R.A. Arc.	Dec.
		s	"	"			s	"	"
Jan.	2	+·18	+2·5	0·0	July	5	+·26	+3·6	−0·2
	10	+·18	+2·5	0·0		13	+·27	+3·7	0·0
	18	+·16	+2·2	+0·2		21	+·25	+3·5	−0·2
	26	+·17	+2·3	+0·1		29	+·25	+3·5	−0·2
Feb.	3	+·18	+2·5	+0·1	Aug.	6	+·24	+3·3	−0·1
	11	+·19	+2·6	+0·2		14	+·24	+3·3	0·0
	19	+·19	+2·6	0·0		22	+·23	+3·2	0·0
	27	+·19	+2·6	0·0		30	+·23	+3·2	−0·1
Mar.	7	+·19	+2·6	+0·2	Sept.	7	+·23	+3·2	+0·1
	15	+·20	+2·8	+0·1		15	+·22	+3·0	−0·1
	23	+·20	+2·8	+0·1		23	+·21	+2·9	0·0
	31	+·22	+3·0	+0·2	Oct.	1	+·20	+2·8	0·0
April	8	+·21	+2·9	+0·2		9	+·20	+2·8	−0·2
	16	+·23	+3·2	+0·4		17	+·20	+2·8	−0·1
	24	+·23	+3·2	+0·4		25	+·15	+2·1	−0·1
May	2	+·24	+3·3	+0·2	Nov.	2	+·19	+2·6	0·0
	10	+·24	+3·3	−0·1		10	+·18	+2·5	−0·1
	18	+·23	+3·2	+0·2		18	+·16	+2·2	+0·1
	26	+·25	+3·5	+0·1		26	+·16	+2·2	+0·1
June	3	+·25	+3·5	+0·3	Dec.	4	+·19	+2·6	+0·1
	11	+·25	+3·5	+0·3		12	+·18	+2·5	+0·1
	19	+·26	+3·6	+0·1		20	+·16	+2·2	0·0
	27	+·26	+3·6	0·0		28	+·17	+2·4	0·0

SATURN, 1901.

Corrections to Le Verrier's Tables.

Day. 1901.		R.A. Time.	R.A. Arc.	Dec.	Day. 1901.		R.A. Time.	R.A. Arc.	Dec.
		s	″	″			s	″	″
Jan.	2	−·24	−3·3	+0·4	July	5	−·30	−4·2	+0·2
	10	−·25	−3·5	+0·2		13	−·29	−4·0	+0·2
	18	−·25	−3·5	+0·2		21	−·27	−3·8	+0·4
	26	−·28	−3·9	+0·2		29	−·25	−3·5	+0·3
Feb.	3	−·29	−4·0	+0·1	Aug.	6	−·24	−3·3	+0·2
	11	−·30	−4·2	+0·1		14	−·24	−3·3	+0·4
	19	−·32	−4·5	0·0		22	−·23	−3·2	+0·3
	27	−·31	−4·3	+0·1		30	−·22	−3·0	+0·3
Mar.	7	−·31	−4·3	+0·1	Sept.	7	−·20	−2·8	+0·5
	15	−·35	−4·9	0·0		15	−·19	−2·6	+0·4
	23	−·35	−4·9	0·0		23	−·19	−2·6	+0·3
	31	−·34	−4·7	+0·1	Oct.	1	−·18	−2·5	+0·5
April	8	−·36	−5·0	0·0		9	−·19	−2·6	+0·5
	16	−·35	−4·9	0·0		17	−·17	−2·3	+0·4
	24	−·35	−4·9	+0·1		25	−·19	−2·6	+0·1
May	2	−·35	−4·9	0·0	Nov.	2	−·21	−2·9	+0·3
	10	−·34	−4·7	−0·1		10	−·19	−2·6	+0·3
	18	−·34	−4·7	+0·1		18	−·19	−2·6	+0·2
	26	−·32	−4·5	0·0		26	−·20	−2·8	+0·2
June	3	−·34	−4·7	+0·1	Dec.	4	−·20	−2·8	+0·2
	11	−·33	−4·6	+0·1		12	−·22	−3·1	0·0
	19	−·30	−4·2	+0·1		20	−·21	−2·9	0·0
	27	−·30	−4·2	+0·1		28	−·22	−3·1	+0·1

Note on the Geographical Position of the University Observatory, Oxford. By A. J. Walker, M.A.

[Introductory note by H. H. Turner, Savilian Professor.—Since my appointment at the end of 1893 the Astronomical work of the Observatory has been that of the Astrographic Chart, and no precise determination of the position has been required. It has been realised, however, that the accepted position is defective, and as soon as opportunity offers a more exact determination will be made. Meanwhile the following statement by Mr. Walker summarises the available information. I am much

obliged to him for the time and trouble he has expended in making these measurements. -H. H. T.—1899 August.]

In *Astronomical Observations made at the University Observatory, Oxford*, No. 1 (published in 1878), at p. vi of the introduction will be found the following statement: "The geographical position of the Observatory, as given in a communication from the Ordnance Survey Department, under the direction of Col. Sir H. James, is as follows:

Longitude West of Greenwich	1° 15′ 5″·991
North Latitude	51° 45′ 34″·152."

This is the position which has appeared in the *Nautical Almanac* ever since, the longitude of course being expressed in time— $5^m\ 0^s{\cdot}4$ west. The *Almanac* for 1898 gives as the source of its information Lancaster's *Liste Général*. This was the first year that the *Almanac* contained the source from which the positions of observatories were derived.

In 1897 some Z D. observations made with the Barclay Transit Circle of the University Observatory exhibited considerable discordances. In recording these observations Prof. Turner wrote: "These disocordances could not be attributed to any known cause. Later it was found that the O.G. was possibly loose (see collimation observations). But the matter requires clearing up. The assumed latitude is possibly to some extent in error, though this cannot explain the whole discordances. From differential observations on the Radcliffe Observatory it would appear that the latitude should be 1″ or 2″ smaller."

Unfortunately the communication from the Ordnance Survey Department does not seem to have been preserved; at any rate, it cannot now be found. There is, however, among the records of the Observatory a paper purporting to show the orientation of the building, and stating that the orientation is 5 inches out in the length of the building. This was apparently communicated by the Ordnance Survey Department

The position of the University Observatory, carefully taken from the 6 inch Ordnance Map (R.F. $\frac{1}{10560}$), is:—

Longitude 1° 15′ 6″·6 or $5^m\ 0^s{\cdot}5$ W., Latitude 51° 45′ 33″·8 N.,

or 0″·6 ($0^s{\cdot}1$ nearly) = 37·7 feet further west and 0″·4 = 40·6 feet further south than the position furnished by the Survey Department. But it would not be difficult to make an error of 0″·2 in taking off the position, and it is difficult to exactly define the point on the map which represents the position of the Transit Circle.

But the position of the University Observatory may be

[redacted]

obtained in another way. Its bearing and distance from the Radcliffe Observatory may be determined, and the difference of latitude and longitude so obtained may be applied to the received position of the latter Observatory. There is, however, apparently no record of this having been done till 1897. Certain differential observations made in that year have already been mentioned. Measurements have now been made upon the 25-inch Ordnance Map (R.F. $\frac{1}{2500}$), and from these the University Observatory would appear to be 358 feet to the south and 2,425 feet to the west (true) of the Radcliffe Observatory. The first of these distances is equivalent to a difference of latitude of $3''.5$, while the second corresponds to a difference of longitude of $38''.5$ or $2^s.6$. If we take the position of the Radcliffe Observatory from the N.A. for 1898 we have :—

	Longitude.	Latitude.
	m s	° ′ ″
Position of Radcliffe O from N A.	5 2·6 W.	51 45 35·4 N.
Diff. Long. and Lat. from Map	−2·6	−3·5
Resulting position of U.O.O.	5 0·0 W.	51 45 31·9 N.
Position of U.O.O. from N.A.	5 0·4 W.	51 45 34·2 N.
Difference	0·4 = 377 feet	2·3 = 233 feet

If the relative position of the two Observatories be correctly laid down on the 25-inch Ordnance Map, it follows that the position of the University Observatory furnished by the Ordnance Survey Department differs considerably from that obtained by astronomical observations, unless indeed a large error has been made in taking the measurements from the map.

Apart from any mere inaccuracy in writing down the result of the measurements, the scale of the 25-inch map is such that a greater error than 5 feet should not be possible in taking off a distance, but it is of course not very easy to say which are the points on the map which represent the position of the Transit Circles of the two Observatories.

A measurement of the difference of latitude on the 6-foot map gave 352 feet—a difference of 6 feet from that obtained from the 25-inch map.

It now remains to check the distance between the two Observatories obtained from measurement upon the Ordnance Map, and to consider with what accuracy the position of the Radcliffe Observatory given in the *Nautical Almanac* has been determined. The second question will be first considered.

From the *Radcliffe Observations* some information can be obtained as to the determination of the position of the Observatory. In the 1841 volume (published 1843) we find the following, p. xv : "In all interpolations from the *Nautical Almanac*, the longitude of the Observatory has been considered $5^m\ 2^s.6$ W. of Greenwich, which is the result of a most careful Chronometrical

determination in the course of 1842 by the Rev. Richard Sheepshanks, the details of which I hope will be soon published." They were apparently not published in the Radcliffe Volumes, and nothing regarding them has been found in either the *Philosophical Transactions*, the *Proceedings* of the Royal Society or the *Monthly Notices* or *Memoirs* of the Royal Astronomical Society. Mr. Sheepshanks died in 1855. See memoir in *Proceedings Royal Society*, where various longitude determinations carried out by him in 1843 and one or two other years are mentioned, but none in 1842.

The longitude has also been obtained by observations of the Moon's R.A. at Oxford and Greenwich from 1864 to 1868 inclusive, and in the 1868 volume of *Radcliffe Observations* we read, p. xxxv: "The most probable result is $5^m\ 3^s{\cdot}66$ W., and this is in excess of the received longitude by $1^s{\cdot}06$. It must not, however, be assumed that the latter is erroneous to that amount . . ."

It would seem as if preparations were at one time made for a telegraphic determination of the longitude. It is said that a wire was laid from the Observatory to the Great Western Railway telegraph system. People now living have seen the wire dug up in the Observatory grounds and in the streets. There is also an old chronograph in the Library, which seems to point to preparations for a telegraphic determination, but no reference to the matter has been found in the annual volumes, and nothing is known about it by the present staff of the Observatory.

In 1840 the latitude adopted was $51°\ 45'\ 36''{\cdot}0$, and this appeared as the latitude in the *Nautical Almanac* for a long time – in fact, until the present value was substituted in 1898. In 1880 $51°\ 45'\ 35''{\cdot}16$ was adopted, and used up to 1888. In the 1888 1889 volume, we find the following remarks, p. xiv: "The assumed position of the Transit Circle of the Observatory employed in the reductions has been

Longitude	$5^m\ 2^s{\cdot}6$	West of Greenwich.
Latitude	$51°\ 45'\ 35''{\cdot}16$ North.	

The latitude used in these reductions is that which has been adopted in the Annual Volumes since 1880, but is not that which is adopted in the General Catalogue of Stars for 1890, which is $51°\ 45'\ 35''{\cdot}39$."

It may here be remarked that the Carrington Transit Circle was brought into use in 1862, having been mounted in exactly the same position as the old Transit. Previous to the erection of the Transit Circle the observations from which the values of the latitude were obtained were made with the Mural Circle. The values of the latitude obtained from observations made in various years have been taken from the Annual Volumes, and are given on next page.

Year.	Latitude.	
1840	51° 45′ 35″·85	
1841	35·97	
1842	35·70	
1843	35·82	
1854	35·31	
1861	35·88	
1862	35·85	
1863	35·73	
1864	35·50	
1865	35·28	
1880	35·17 with a weight of	53·6
1881	34·95	76·7
1882	35·24	111·5
1883	35·23	55·6
1884	35·49	29·5
1885	35·43	25·1
1886	35·67	5·1
1887	35·73	19·9

For further information regarding the value adopted for the 1890 Catalogue see the introduction to the Catalogue.

In order to check the measurements taken from the 25-inch Ordnance Map, the following measurements were made on the ground in 1899 May

On May 18 a line was set out northwards towards the cricket pavilion with the Barclay Transit Circle for a distance of 575 feet, trees preventing its being carried any further. The line was first set out with ranging rods, it being possible to see these pretty distinctly with the Transit Circle when a piece of cardboard with a small hole in it was placed in front of the O.G. The rods were then replaced by pegs into which copper tacks were driven for the purpose of more accurately defining the line.

Then, by means of a right-angled prism, the point was found in the meridian line in which that line was cut at right angles by a line from the centre of the globe on the top of the tower of the Radcliffe Observatory. The distance from this point to the Barclay Circle was found by the tape to be 359 feet, differing but 1 foot from the distance as measured on the 25-inch Ordnance Map.

The distance was then measured between two points on the meridian line from both of which the Radcliffe Observatory was visible. The mean of two measurements (which differed by ½ inch) with a 100-foot steel tape gave 334 feet 0¼ inch. The angle formed at each end of this base with the globe on the Radcliffe

tower was then measured several times on different days with a 5-inch theodolite by Messrs. T. Cooke & Sons, of York.

The distance between the centre of the Radcliffe hall (which is assumed to be directly below the centre of the globe) and the Radcliffe Transit Circle was measured with a steel tape and found to be 44·62 feet.

As a further check, two traverses were made with the 5-inch theodolite and Chesterman 100-foot steel tape between the two Observatories, and by the kindness of the Radcliffe Observer it was possible to carry them right up to the Radcliffe Transit Circle. Owing to bad weather and difficulties caused by traffic, these measurements were made on different days and at different times of day. Every line was measured twice when possible. In most cases the back station was observed first, the theodolite being first set to zero. The compass was used as a check in the first traverse, and showed the presence of a good deal of local attraction. Details of the measurements follow :—

Summary of Results of Measurements.

	Difference of Latitude. Feet.	Departure. Feet.	
	357·65	2419·47	1st Traverse
	358·95	2418·67	2nd „
	356·47	2417·92	1st Triangulation
	356·64	2419·02	2nd „
4 /	29·71	35·08	
Mean	357·43	2418·77	

357·43	2418·77	From the various measurements.
358·00	2425·00	From the 25-inch map.
352·00		„ „ 10-foot „

Taking the difference of latitude as 357·43 feet and the departure as 2418·77 feet, and the value of 1″ of latitude as 101·38 feet and 1″ of longitude as 62·92 feet, we have :—

Difference of Latitude 3″·53. Difference of Longitude 38″·44 = 2ˢ·56.

Distance 2445·0 feet. Bearing N. 81° 35′ 40″ W.

Hence the University Observatory is :

3″·53 South of the Radcliffe Observatory

and 38″·44 or 2ˢ·56 East „ „ „

while the Radcliffe Observatory bears from it N. 81° 35′ 40″ W. true, distant 2445 feet.

The measurements actually made on the ground agree, therefore, closely with those made on the 25 inch Ordnance Map, and

give what is practically precisely the same difference of latitude and longitude.

The difference between the position of the University Observatory obtained by applying this difference of latitude and longitude to the N.A. position of the Radcliffe Observatory and the position furnished by the Ordnance Survey Department is, then, $0^s.4$ in longitude and $2''.3$ in latitude.

On 1899 July 18 a letter was written to the Director-General of the Ordnance Survey, giving the same details substantially as those here given, and asking for information on the subject. This letter was acknowledged by return of post, and a reply, dated 1899 August 2, subsequently received. This reply is appended.

Ordnance Survey Office,
Southampton, 1899 August 2.

Dear Sir,—The question raised in your letter of 18th ultimo has been investigated. Unfortunately, the data on which Sir H. James reported the latitude and longitude of the University Observatory, Oxford, cannot be found.

The positions of the University and Radcliffe Observatories as shown on our maps have been checked, and there seems no doubt as to their correctness; but the only satisfactory way of clearing up the discrepancies would be to connect the Observatories with the triangulation of the Ordnance Survey. This would take some time and entail some expense, and could not be undertaken without the sanction of the Board of Agriculture.

Yours faithfully,
Duncan A. Johnston, Colonel.

A. J. Walker, Esq.

The reply would seem to carry the matter very little, if any, further. Information was asked as to the difference between positions in or near Oxford as determined by geodetic operations and astronomical observations, but none is given. One would not naturally expect a large deflection of the vertical in Oxford. Clarke, however, remarks in his *Geodesy*, 1880, at p. 287, "The discordances resulted from the fact with which we are now familiar, that the observed latitude of any station, although from its surroundings it may be apparently quite free from any suspicion of local attraction, is yet liable to an error of one or two seconds. This amount is, indeed, often exceeded, and it is not very uncommon to find, as in the vicinity of Edinburgh, a deflection of gravity to the extent of $5''$ . . ." Gillespie also remarks (*Higher Surveying*, 1897, at p. 196), "An examination of the local deflection of the vertical (plumb line) at latitude stations shows that the determination of astronomic latitude with an accuracy of about a quarter of a second is quite sufficient for most schemes of triangulation, being considerably within the limits of the ordinary deflections. A greater precision is necessary in locating state and national boundaries and determining arcs."

Variation of latitude, the range of which is apparently between 0''·2 and 0''·7, would not go far towards explaining a discrepancy of 2''·3.

On the Optical Distortion of a Doublet Lens. By Captain E. H. Hills, R.E.

In the May number of *Monthly Notices*, Professor Turner has discussed the distortion of a doublet lens, and has shown that it is at all events probable that it is a negligible quantity over a field of 11° square.

In my investigation on the determination of longitudes by photography (*Memoirs R.A.S.* vol. liii.), it was necessary to satisfy myself, before applying the formulæ of reduction to the star places, that any possible optical distortion of the lens employed did not introduce a measurable factor into the results, and I accordingly carried out some experiments on this point.

The results I arrived at were practically identical with those reached by Professor Turner, but as I approached the subject by a different road it seems desirable to give a short account of the work. The method used was to set up the camera in a fixed position, and, leaving the lens open for a considerable time, a number of star trails were drawn across the plate. The curvature of these trails was then measured and compared with the calculated amount.

For convenience of computation, the camera was so arranged that the projection of the equator fell near the centre of the plate. This is not absolutely necessary, as the rigorous formulæ present no special difficulty; but, as will be seen immediately, the employment of a simple, approximate formula for the curvature does not introduce any appreciable error until the centre of the plate is moved many degrees from the equator.

The theoretical curvature of a star trail on the plate may be derived as follows:

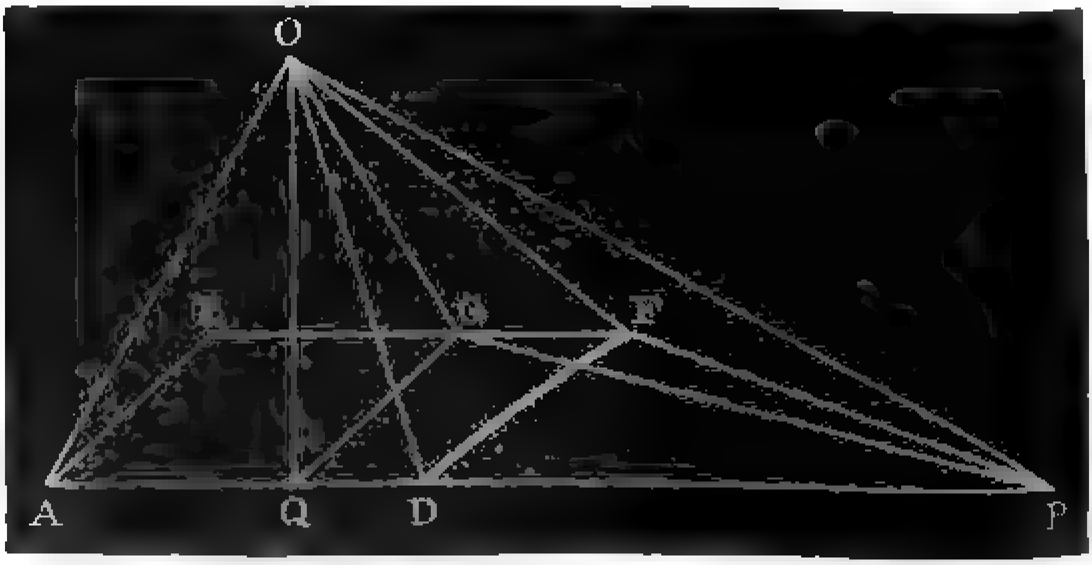


Fig. 1.

Q is the 'centre' of the plate—*i.e.* the foot of the normal from the centre of the lens on the plate.

O is the centre of projection—*i.e.* the optical centre of the lens.

AE is the projection of the equator.

P is the projection of the pole.

DF is any star trail.

The line EF is drawn on the plate parallel to AP at any arbitrary angular distance from it, and QG is parallel to AE.

Let

$$QOG = \theta.$$

$$OQ = \text{radius} = 1.$$

$$QOA = \text{declination of centre of plate} = \phi.$$

$$DOA = \text{declination of star} = \delta.$$

Then GF—QD is the curvature required.

We have

$$QG = \tan\theta.$$

$$QP = \cot\phi.$$

$$\tan QPG = \tan\theta\tan\phi.$$

$$= \tan\alpha.$$

In the triangle GOP

$$OG = \sec\theta.$$

$$OP = \operatorname{cosec}\phi.$$

$$GP = \tan\theta\operatorname{cosec}\alpha.$$

$$\cos GOP = \frac{\sec^2\theta + \operatorname{cosec}^2\phi - \tan^2\theta\operatorname{cosec}^2\alpha}{2\sec\theta\operatorname{cosec}\phi}$$

but

$$\operatorname{cosec}^2\alpha = 1 + \cot^2\alpha = 1 + \cot^2\theta\cot^2\phi.$$

Therefore,

$$\cos GOP = \frac{\sec^2\theta + \operatorname{cosec}^2\phi - \tan^2\theta - \cot^2\phi}{2\sec\theta\operatorname{cosec}\phi}$$

$$= \cos\theta\sin\phi.$$

$$= \cos\beta.$$

In the solid figure OGFP, taking the angles at G, we have

$$OGF = 90^\circ$$

$$FGP = \alpha$$

and angle between planes OGF, FGP $= 90^\circ - \theta$.

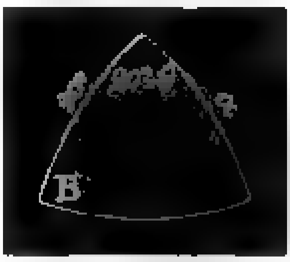


Fig. 2.

Then, if B = angle between planes OGF, OGP,

$$\tan B = \tan \alpha \cos \theta$$
$$= \sin \theta \tan \phi.$$

Again taking the angles at O, we have

$$FOP = 90^\circ - \theta.$$
$$GOP = \beta.$$

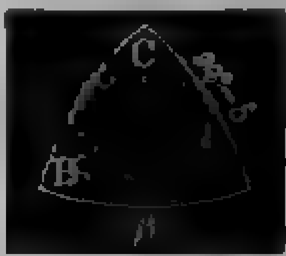


Fig. 3.

Then if C = angle between planes FOP, GOF

$$\sin C = \frac{\sin B \sin \beta}{\cos \delta}$$

and

$$\tan \frac{GOF}{2} = \frac{\sin \frac{B+C}{2}}{\sin \frac{B-C}{2}} \tan \frac{90^\circ - \delta - \beta}{2}$$

$$= \tan \frac{\gamma}{2}.$$

We have therefore finally as the expression for the curvature—

$$GF - QD = \sec \theta \tan \gamma - \tan (\delta - \phi)$$

where

(1) $\tan \dfrac{\gamma}{2} = \dfrac{\sin \frac{B+C}{2}}{\sin \frac{B-C}{2}} \tan \dfrac{90^\circ - \delta - \phi}{2}$

(2) $\sin C = \dfrac{\sin B \sin \beta}{\cos \delta}.$

(3) $\tan B = \sin \theta \tan \phi.$

(4) $\cos \beta = \cos \theta \sin \phi.$

The angle θ can be selected any convenient magnitude, say 5°, and it is then easy to construct a table of double entry, giving the value of the curvature at any distance from the centre. In practice, however, this is unnecessary. It is obvious that when ϕ is small the expression for the curvature becomes

$$\tan \delta (\sec \theta - 1),$$

and the difference between this approximate value and the true one will remain quite negligible even when ϕ amounts to many degrees.

Thus taking $\theta = 5°$ and values of δ between 0° and 10°, it will be found that, even when $\phi = 8°$, the difference between $\sec\theta \tan\gamma - \tan(\delta-\phi)$, and $\tan\delta(\sec\theta - 1)$ does not amount to a unit in the 7th place of decimals, *i.e.* does not exceed 0''·02.

In taking the test plate there can be no possible difficulty in so adjusting the camera that the centre lies near the equator, and the theoretical curvature of a trail can then be deduced in the above simple manner.

As an example of the method the results obtained with an actual plate may now be given.

The lens in this case was a Zeiss anastigmat of 377 mm. focal length. The micrometer used read to ·001 mm., equivalent to 0''·6 of arc on the plate. An error of four times this amount, or between 2'' and 3'', is quite possible in any individual measurement.

The measures may therefore be taken as qualitative rather than quantitative, as it is obvious on inspection of the residuals that there is no measurable distortion over the field taken—namely, to a distance of about 9° from the centre, equivalent to a square plate of about $12\frac{1}{2}°$.

Table Giving Results of Test of Zeiss Anastigmatic Lens.

$$\begin{cases} r = 377 \text{ mm.} \\ \theta = 5° \\ \phi = 24' \end{cases}$$

Star.	δ	Distance from Centre of Plate.	Curvature in Millimetres. Observed.	Calculated.	O−C	O−C in Arc.
	° ′	° ′				″
1	−1 16	0 52	·030	·030	±·000	±0·0
2	−2 0	1 36	·049	·050	−·001	−0·6
3	−2 40	2 16	·067	·066	+·001	+0·6
4	+3 0	3 24	·080	·075	+·005	+2·9
5	+4 3	4 27	·099	·102	−·003	−1·7
6	−4 54	4 30	·121	·124	−·003	−1·7
7	+5 52	6 16	·149	·148	+·001	+0·6
8	−5 58	5 34	·151	·150	+·001	+0·6
9	+6 15	6 39	·165	·159	+·006	+3·4
10	+7 23	7 47	·188	·186	+·002	+1·1

As Prof. Turner has pointed out, the effect of refraction is practically eliminated by taking the measurements in the form of differences of curvature of two trails. This was done in the above example. The trail of a known star (δ *Orionis*), near the centre of the plate, was taken as the fiduciary line from which the measurements were made, and the deduced curvatures were

then corrected by adding or subtracting the calculated curvature of this trail. These residuals will no doubt at first sight appear large to those accustomed to work with instruments of long focal length, but it must be borne in mind that these same quantities expressed in linear measurement, which is really fairer for purposes of comparison, are extremely small. The unit of measurement used—namely, ·001 mm.—certainly represents the extreme limit of accuracy, if indeed it be not beyond it, that can be obtained from any stellar photograph. If a more liberal standard of accuracy were adopted the appearance of the residuals would be correspondingly improved. Thus taking the standard of the astrographic plates and carrying the measurements, as is done with them, only to a limit of ·005 mm., it will be seen at once that nearly all the residuals would be zero.

It may further be noted that, as any distortion which is linear in r will disappear in the reduction to rectilinear co-ordinates, we are entitled to assume that value of r which will make the sum of the residuals a minimum, provided always that there be sufficient stars on the plate to give a real value of r. In this example, as all the residuals are practically within the limits of possible errors of measurement, a correction of the assumed value of r would be unnecessary and hardly justifiable.

List No. 12 of Nebulæ discovered at Lowe Observatory, Echo Mountain, California, for 1900·0. By Lewis Swift.

No.	Date 1898.	R.A. h m s	Dec. ° ′	Description.
1	May 24	0 4 10	−32 49·9	vF, vS, R, unequal D ✱ n.
2	24	0 5 30	− 7 58·3	eeeF, vS, R, bet 7½ᵐ ✱ n and 9ᵐ ✱ s, eee dif.
3	22	0 29 40	−30 32·9	eeeF, S, R, wide D ✱ close p point to it. Not 174.
4	Nov. 19	0 53 0	−17 ?	pF, vS, 7¼ᵐ ✱ np, F ✱ near s p.
5	1897. May 24	1 0 0	−27 56·4	eF, pS, close to 3 st like belt of Orion
6	Oct. 12	1 4 0	−29 6·6	cB, pS, R, 3 8ᵐ st near.
7	Sept. 20	1 28 0	−14 0·8	eeF, R, S, lE, 8ᵐ ✱ n, e dif.
8	Oct. 10	1 54 15	−28 16·5	eeF, S, R, 8ᵐ ✱ S, lf.
9	Previous	11 49 ?	− 5 ?	eeF, lE, v small, 3 B st in line n, also circle of st n. Saw it twice, failed once.
10	June 24	12 15 5	+61 15·0	eeeF, S, 7½ and 5ᵐ st in field, p of 2. One of my faintest nebulæ.
11	24	12 15 35	+61 15·0	vF, pL, R, 7½ᵐ ✱ south, f of 2.
12	Aug. 19	15 29 ?	+ 6 21·0	eeeF, L, R, eee dif.
13	19	15 50 ?	+ 6 19·0	eF, S, R, bet 8ᵐ ✱ f, and curve of st p.
14	16	19 41 20	−33 34·0	eeeF, eeS, eee dif sev F st near.

No.	Date 1897.	R.A. h m s	Dec. ° ′	Description.
15	Sept. 11	19 59 0	−44 19·3	eF, S, R, 3 or 4 st f, form with the neb, a circle, sp of 2.
16	17	19 59 30	−43 59·3	vF, pS, R, bet a wide D ✱ f and a ✱ np, nf of 2.
17	11	20 17 25	−38 33·9	eF, pS, R, bet 2 8½ᵐ st nf and sp.
18	8	20 19 0	−30 11·8	vF, C, S, R, 2 st nr sf, point to it. Sp of 2.
19	8	20 19 25	−30 1·8	eeF, C, L, R, bet 2 groups of B st sf, and np, nf of 2.
20	Aug. 18	20 22 20	−32 1·9	pB, pS, R, nearly bet 2 st with dist. companion.
21	Sept. 11	20 24 0	−38 32·9	eF, pS, R, bet 2 8½ᵐ st nf and sp.
22	July 26	20 34 10	−30 11·6	eeF, eS, eE, F ✱ with dist. com. nr sf, point to it, np of 2.
23	26	20 34 30	−30 12·6	eeeF, vS, cE, ee dif, sf of 2.
24	Sept. 8	20 44 10	−30 11·8	vF, pS, R, 8ᵐ ✱ in margin of field n.
25	Aug. 19	21 18 0	−41 3·3	vF, vS, R, ✱ with dist. com. n and s.
26	July 24	21 36 30	−39 27·0	eeeF, vS, R, 5 or 6 st nr sp, v dif.
[illegible]	Sept. 15	21 42 55	−34 7·0	eeF, S, R, wide D ✱ points to it, sev pB st sf and np.
28	Aug. 18	21 44 50	−31 26·8	vF, S, lE.
29	July 23	21 53 0	−39 52·8	vF, L, lE, 2 B st point to it, nearest in contact.
30	Sept. 8	21 53 0	−27 51·5	eF, S, R, 6½ᵐ ✱ same parallel follows 63ˢ.
31	July 26	21 57 0	−35 27·1	pB, pS, R, 3 st in line nr nf.
32	Oct. 16	21 57 26	−34 17·0	pF, pS, R, in vacancy.
33	July 26	22 7 25	−37 22·5	vF, L, R, ✱ close S, B ✱ sp.
34	Sept. 20	22 9 30	−36 20·3	pB, C, S, F ✱ in contact sf, sev pB st form segment of large circle.
35	July 19	22 9 35	−37 22·4	pF, pS, lE, bet 2 st in meridian, 8½ᵐ ✱ sp, np of 2.
36	19	22 10 25	−37 20·4	eeF, S, R, F ✱ nr p, 8ᵐ ✱ np, sf of 2.
37	26	22 18 5	−27 58·5	eF, pS, R, 8ᵐ ✱ p.
38	Oct. 6	22 26 0	−25 52·6	eeF, pS, R, bet 2 st, a dozen st in margin of field f, form semicircle 4 st np a curve, one D, sp of 2.
39	6	22 26 10	−25 10·3	eeeF, pL, R, no ✱ nr, trapezium, nf of 2.
40	July 19	22 34 20	−30 31·6	eeeF, eeeS, eeeE, eee dif, a line. 8ᵐ ✱ np.
41	19	22 49 0	−37 53·5	eeF, pS, R, 9ᵐ ✱ nr sp, ee dif.
42	Aug. 22	22 49 40	−34 22·0	eeeF, pS, R, bet a ✱ p and a wide D nf, 8ᵐ ✱ f, eee dif, np of 2.
43	22	22 52 30	−34 17·0	pF, pS, vE, bet 2 st.
44	July 26	23 13 0	−10 50·6	eF, S, R, 3 or 4 F st nr sp.
45	24	23 47 0	−29 11·4	vF, eS, R, 3 st in line p, one D.

Lowe Observatory:
1899 July 9.

The Magnitude of η Argûs, 1899. By R. T. A. Innes.

The comparison stars for *η Argûs* given in the *Uranometria Argentina* only go to the 7·60 magnitude, and fainter magnitudes are now required.

For the present it has been found sufficient to add the star C.G.A. Cluster Catalogue, No. 121, there given as mag.=8·0 red. I have used this magnitude; the colour is about 8 on Chandler's scale. The other comparison star used in the following observations was Gilliss 1331, mag. 7·60; colour, full yellow = 4 on Chandler's scale.

Both of these stars are most conveniently situated with reference to *η Argûs*, which is between them in position, and also at present between them in magnitude and colour.

With the 7-in. Merz equatorial :—

1899 June	10	mag. = 7·6	
	11	7·8	colour = 8.
	13	7·75.	
	18	7·7	colour = 6
1899·5		mag. 7·71	colour 7.

To compare we have :—

1897·2	7·60	See, A.J. 399, p. 119.
1896·4	7·58	Innes, M.N. lvii p. 115
1886·2	7·60	Finlay, „ xlvi p. 340.

All in U.A. scale

Royal Observatory, Cape of Good Hope,
1899 June 20.

Tempel's Comet (1873 II *c* 1899), *observed at Grahamstown.* By Major L. A. Eddie.

1899, August 15.—Comet well seen, though Moon too bright for detecting much physical structure. Head sharply defined on preceding edge, narrow in anterior portion, spreading out immediately at a wide angle, and very much diffused posteriorly. Condensation in central portion of head. Colour pale white, but moonlight too bright to detect any particular tint. This comet did not appear fluffy, like Swift's comet observed at my observatory in March last, but with a sharp outline on advancing edge. Though faint, stood power of 100 well.

August 17.—Moon very bright, and atmosphere hazy, so comet only dimly visible.

August 18.—Comet nearly eclipsed by moonlight, though could be traced as well spread out, with central portion fairly condensed. Colour very pale bluish white.

August 24.—Early evening, dark. Comet well seen in finder. In 9¼-inch reflector nucleus globular in form, and well condensed, of pale white colour, about 2′ in diameter, and surrounded by wide but very rare coma. A broad, though extremely faint, tail, could be traced to about 16′.

Spectroscope gave dim continuous spectrum, with brighter concentration in one portion, but no bands detected.

August 25.—Comet well seen on dark background. Cometic envelopes, though faint, well defined, with two dark intervals in preceding portion, fairly conspicuous condensed nucleus, with dark rift behind, and broad, faint tail about 16′ in length. No bands detectable with spectroscope.

August 28.—Comet already much fainter. Detail not well seen, but considerable surrounding coma still visible. Stellar point in condensed portion suspected. Comet subsequently observed on August 29, 31, September 1, 2, 5, 7; but no great changes detectable, only getting gradually fainter, though condensed nucleus and wide spread surrounding coma in hyperbolic form still noticeable; dark rift in faint tail generally seen, coma usually showed a very streaky appearance.

Approximate Positions.

	G. U. T.		R.A.		S. Dec.			C. U. T.		R.A.		S. Dec.	
	h	m	h	m	°	′		h	m	h	m	°	′
Aug. 15	11	0	21	12	31	4	Aug. 29	8	0	21	29	35	0
17	10	0	21	13½	31	33	31	8	0	21	31¾	35	16
18	10	0	21	14½	32	12	Sept 1	8	0	21	33	35	24
24	10	0	21	22½	33	54	2	9	30	21	34½	35	32
25	9	15	21	23¾	34	21	5	8	30	21	38½	35	49
28	8	30	21	27½	34	51	7	8	15	21	40	36	0

Grahamstown:
Sept. 9, 1899.

Observations of Jupiter in 1899. By W. F. Denning.

Between 1899 February and September (but chiefly in the months June to September) I obtained 668 transit times of various markings on *Jupiter*. All the observations were effected by the help of a 10-inch With-Browning reflector and one of Steinheil's monocentric oculars having a power of 312. It is not intended to give the details of the observations,* but simply

* This is rendered unnecessary by the fact that Mr. A. S. Williams of West Brighton is investigating the motion of the equatorial current, while the Rev. T. E. R. Phillips, of Yeovil, is discussing all the observations of spots in the extra-equatorial currents.

a condensed summary of the principal results, as they may be useful in this form to compare with my similar results for 1898 (*Monthly Notices*, lviii. p. 480 *et seq.*).

Equatorial Spots. Twenty-seven white and dark spots situated on the N. edge of the great S. equatorial belt gave a mean period of

$$9^h\ 50^m\ 24^s{\cdot}6.$$

This is one second greater than the rate derived from 23 similar markings observed here in 1898, so that the equatorial current (or at any rate that section of it contiguous to the S. belt) has slightly moderated its velocity during the last twelve months. There were large differences (as in 1898) in the periods found from the individual spots in this latitude. The maximum period was $9^h\ 50^m\ 35^s$, the minimum $9^h\ 50^m\ 18^s$. The average number of observations of each of the spots was 11, and the number of rotations 255.

North Tropical Spots.—Sixteen white and dark spots on the north side of the northern equatorial belt indicated a mean period of

$$9^h\ 55^m\ 28^s{\cdot}8\ ;$$

but in this latitude also the various objects gave very discordant rates. Three of them moved with remarkable swiftness, and had a mean period of $9^h\ 55^m\ 16^s{\cdot}4$, while 13 others gave $9^h\ 55^m\ 32^s{\cdot}5$. The average number of observations for each marking was 7, and the rotations performed 153. In 1898, three dark spots in this current gave a period of $9^h\ 55^m\ 26^s{\cdot}3$.

Markings in Southern Hemisphere. Three spots in latitude about 25° to 30° S. had a mean period of

$$9^h\ 55^m\ 18^s{\cdot}6.$$

Two other objects further south, in about lat. 40° to 50° S., moved more rapidly, the rate being

$$9^h\ 55^m\ 9^s{\cdot}2.$$

Markings in Northern Hemisphere.—Two well defined dark spots were watched in lat. 25° to 30° N., and they exhibited a considerable difference of motion. One, which was nearly in the same longitude as the red spot in 1899 March, indicated a period of

$$9^h\ 55^m\ 29^s{\cdot}8$$

The other moved more slowly than any other object on the disc of the planet, its rate being

$$9^h\ 55^m\ 53^s{\cdot}5.$$

The Red Spot and Hollow in the S. Hemisphere.—The spot continued exceedingly faint in 1899, but on a night of good definition its complete elliptical outline could be distinctly perceived except perhaps its extreme southern side, where it appeared to blend with the dusky south temperate belt. The *f* end of the spot was more distinct than the *p* end, and this has been the common experience in recent years. The hollow in the great southern equatorial belt seems to follow the spot by 2 or 3 minutes; but this appearance is due to a difference in the form of the shoulders of the hollow. The *p* side is flatter than the *f* side, hence the spot seems naturally to lean towards the latter. As the hollow in the belt is a very conspicuous feature and exhibits precisely the same rotation period as the red spot, and as the latter is often partly or wholly obliterated in bad definition, I obtained transits of the centre of the former object as the times may be regarded as practically identical with the times of central transit of the red spot. Between February and September 35 transits were taken, and the first and last of these, as under, appear to accurately represent the position of the object on the two dates:—

	h	m	λ °
1899 February 2	18	39	29·5
September 16	5	41	36·5

545 rotations were performed in this interval, and the mean period was

$$9^{h}\ 55^{m}\ 41^{s}{\cdot}9.$$

This is one-tenth of a second in excess of that deduced from my observations between 1898 March and July. But there is no doubt that, after 1898 July, the spot exhibited a marked acceleration of motion, and it was unfortunate that, during the autumnal months, *Jupiter* was too near to the Sun to permit of the continued observation of this feature. In 1899 February, when the planet came favourably into view, the hollow arrived on the central meridian fully 5 minutes before its computed time. In fact the rotation period of the object varied as follows:—

	h	m	s
1898 March to July ...	9	55	41·8
1898 August to 1899 April	9	55	41·2
1899 May to September ...	9	55	42·0

That this change of rate actually occurred is beyond question, for it is well corroborated by the evidence of other observers.

Early History of the G
By W. F

In the Supplementary Num
I gave some particulars of ob
identical with the great red sp
and rate of motion were found co
varying period of rotation was
accurate recognition of the c
Since this paper was published
observations and drawings of th
equatorial belt, or of the ell
September 5. Though the rec
ellipse, appears to be quite wanti
yet a very well marked hollow in
safely presumed to accurately inc
in several recent years. Before
have been indistinguishable, an
material outlying it above the su
R. Dawes in 1857 figured an
Notices, vol. xviii. p. 50, and Sir
drawings (very excellent copies
this purpose by Lady Huggins)
April, and in many of these a we
is shown in the south hemisphere
Mr. A. Stanley Williams and to
many of Sch

Lit. and Phil. Society of Manchester, session 1859-60, Mr. Baxendell gave eight observed transits of a dark spot in about 28½° * south latitude, visible in the months from 1859 January to April. He determined its mean rotation period as $9^{h}\ 55^{m}\ 37^{s}\cdot812$, and there is no doubt whatever from a comparison with Sir William Huggins's drawings at about the same period, that this spot was really the dark following end of the ellipse. If twenty-seven minutes (=16½° of longitude) are deducted from Mr. Baxendell's transit times they agree as nearly as possible with the estimated times of transit of the middle of the ellipse figured on many occasions by Sir William Huggins. In the following table this deduction has therefore been made in regard to the eight observations alluded to, which have been marked with an asterisk to distinguish them from the other transit times, all of which are dependent upon estimations from the position of the object east or west of the central meridian on drawings.

The transit times, being nearly all adopted from sketches which do not always represent the exact position of the spot or hollow at the minute the sketches were dated, may be sometimes erroneous to the extent of as much as 20 minutes, or possibly, in an exceptional case, 30 minutes. But even a misplacement of this large amount does not seriously impair the value of the rotation period when it is deduced from several years of observation. Thus, an error of 30 minutes would make one second difference in the period of rotation based on two years' observation, 0·68 second on 3 years, 0·54 on 4 years, and 0·41 on 5 years. This is, however, an extreme case, and I have endeavoured to avoid so large an error by testing and correcting the transits employed, by others, whenever practicable, obtained at nearly the same epoch.

Observations of the Hollow in the Great Southern Equatorial Belt or of the Red Ellipse in the South Hemisphere of Jupiter, 1831 September 5 to 1869 November 14.

Observer.	Year, month, and day.	Estimated transit time.	G.M.T. of sketch.	Position of object relatively to the C.M.
		h m	h m	°
H. Schwabe	1831 Sept. 5	8 21	8 56	21 W.
,,	19	9 51	9 11	24 E.
,,	Nov. 5	3 46	3 56	6 W.
,,	1832 Oct. 9	7 31	8 11	24 W.

* This is several degrees south of the position of the red spot in recent years, but it by no means negatives the assumption of identity. The spot varies in latitude (possibly at regular periods) as well as in longitude. Professor G. W. Hough has made a series of measures of the position of the red spot during the last twenty years with a refractor of 18½-inch aperture, and says the object "has drifted in latitude, the total displacement being 2″·1 of arc." The maximum south latitude was in 1886, when the spot was 7″·41 distant from the equator, and the minimum in 1892, when the distance was 5″·32. This represents a difference in latitude of about 7°.

"	1855 Sept.	
"		
"	Oct.	
"	Nov.	
"		
"		
"	1856 Aug.	
"	Sept.	
"		
"	Oct.	2
*Rev. W. R. Dawes	1857 Nov.	2
†Sir W. Huggins	1858 Dec.	2
"	1859 Jan.	1
‡J. Baxendell		2
"	Feb.	
Sir W. Huggins		1
J. Baxendell		1
Sir W. Huggins		1
"		23
J. Baxendell		23
"	Mar.	7
"	Apr.	7
"		9
"		21

Observer.	Year, month, and day.	Estimated transit time.	G.M.T. of sketch.	Position of object relatively to the C.M.
		h m	h m	°
*J. W. Long	1860 Feb. 29	7 55	7 45	6 E.
†Sir W. Huggins	Mar. 2	9 40	9 0	24 E.
‡J. Baxendell	2	9 45	9 24	12½ E.
Capt. W. Noble	2	10 10	10 2	5 E.
‡J. Baxendell	5	7 32	7 18	8½ E.
Capt. W. S. Jacob	12	8 10	7 40	18 E.
Capt. W. Noble	1863 Apr. 28	9 40	9 40	on C.M.
§N. E. Green	May 7	12 10	11 30	24 E.
Capt. W. Noble	7	12 20	10 55	51½ E.
"	17	10 25	9 35	30 E.
T. W. Backhouse	1864 July 19	8 35	9 20	27 W.
"	1867 Aug. 30	10 45	10 10	21 E.
Capt. W. Noble	Sept. 13	12 10	11 54	9½ E.
J. Gledhill	1869 Nov. 14	10 50	..	...

There can be no doubt that, in addition to this, much other evidence of a corroborative nature might be obtained by an exhaustive search amongst old records of Jovian observations. But the above are amply sufficient for the purpose of deriving a trustworthy rotation period for a considerable part of the whole interval. Additional data would, however, be useful for the periods from 1831 to 1850, and 1860 to 1869. Mr. A. S. Williams informs me that Schmidt obtained 300 or 400 drawings of *Jupiter* between 1843 and 1880, and if these could be consulted they would undoubtedly supply much reliable evidence on the early history of the red spot and its surroundings.

From a selection of some of the best observations in the foregoing summary I have worked out the rate of rotation of the spot or hollow in the south equatorial belt, in various years, as follows :—

* The drawing appears in *Monthly Notices*, vol. xx. p. 244.

† *Observatory*, vol. v. p. 49, but the date is there erroneously given as 1858 March 2.

‡ *Monthly Notices*, vol. xx. p. 244. Capt. Jacob's drawing of 1860 March 12 will also be found here.

§ *Astronomical Register*, 1872, fig. 4.

" ...	1855	Sept.	22	3	51
" ...	1856	Sept.	9	10	41
Rev. W. R. Dawes	1857	Nov.	27	7	20
Sir W. Huggins	1858	Dec.	29	10	20
Sir W. Huggins / Capt. W. Noble / J. Baxendell ...	1860 †	Mar.	2	9	52
Capt. W. Noble	1863	May	17	10	25
"	1867	Sept.	13	12	10
J. Gledhill ...	1869	Nov.	14	10	50
H. Schwabe ...	1831	Sept.	5	8	21
J. Gledhill ...	1869	Nov.	14	10	50

For the interval elapsed since observation obtained at Bristol, I fin

				h	m
J. Gledhill ...	1869	Nov.	14	10	50
W. F. Denning	1899	Sept.	16	5	41

For the entire period of 68 years

H. Schwabe ...	1831	Sept.	5	8	21
W. F. Denning	1899	Sept.	16	5	41

* For a similar table to this, carryin see *Monthly Notices*, lviii. p. 491.

† In this case I have taken the mean drawings made on the same evening, and conspicuous feature.

‡ Three more rotations than the total above. This is because Jupiter apparer lution round the Sun, and the rotations g the number observed...

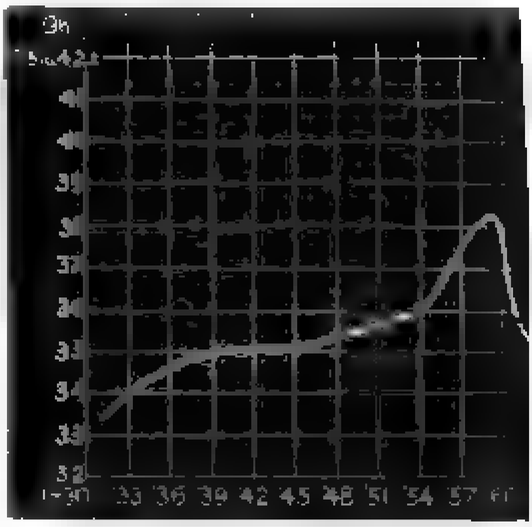
For several of the longer periods, where no intervening observations afford a criterion, the number of rotation periods has necessarily been assumed. It may be thought, therefore, that the precise number employed is open to doubt; but there is little evidence to support this view, as the resulting rotation periods all show a consistent agreement, and there are a few observations near the beginning or closing of several of the periods which prove that the figures are correct. Moreover, if one rotation too many or too little were adopted, it would throw the periods out considerably, and indicate some extraordinary fluctuations in the rate of the spot. Thus, for the longest period (embracing $7\frac{1}{2}$ years) in the table, the assumed number of rotations is 6663. This number gives a period presenting a most suggestive agreement with the others. If 6662 rotations had been adopted, the resulting period would have been $9^h\ 55^m\ 40^s$, and if 6664, $9^h\ 55^m\ 29^s$. These figures are discordant with the rates exhibited during the periods preceding and following. But they are not altogether impossible in view of the irregularities which have been occasionally observed in the motion of the spot. For the smaller periods in the table the number of rotations may be safely regarded as correct, as any other number would give an abnormal period. Still, it is hoped that to ensure absolute confidence in the results obtained, some additional observations will be found to fill up the longer intervals. In consulting old records, references are occasionally met with which undoubtedly refer to the red spot or the accompanying hollow in the southern belt. Thus, Dr. O. Lohse, of Bothkamp, quotes the following observation by the Bonds at Harvard College Observatory. 'On February 3, 1848, at $9^h\ 30^m$ M.S.T. (Camb.) three belts only were seen. The broad one lying a little south of the equator had no longer its sides parallel, as on January 28, but a deep hollow on the south edge, reaching nearly across on the *p.* side.'

Taking the average rotation periods in the foregoing table (1831 to 1869), and those in my previous paper on the same subject (*Monthly Notices*, vol. lviii. p. 491), the smoothed rate in successive years appears to have been as follows:—

Year.	h	m	s	Year.	h	m	s	Year.	h	m	s
1831	9	55	33·3	1841	9	55	35·0	1851	9	55	35·7
1832			33·6	1842			35·1	1852			35·8
1833			33·9	1843			35·1	1853			35·9
1834			34·1	1844			35·2	1854			36·0
1835			34·3	1845			35·2	1855			36·1
1836			34·5	1846			35·3	1856			36·7
1837			34·7	1847			35·3	1857			37·5
1838			34·8	1848			35·4	1858			38·0
1839			34·9	1849			35·5	1859			38·3
1840			35·0	1850			35·6	1860			37·1

	34·4	18…
1871 —	34·4	188
1872 —	34·3	188
1873 —	34·3	188

The rotation period incre
about $9^h\ 55^m\ 33^s$ in 1831 to
rapidly decreased to about 9^h
became very gradual, and dur
1879 inclusive it seems to ha
In 1880 and three following y
so that in 1884 it was $9^h\ 55^m$
the increase was continued, b
period was $9^h\ 55^m\ 41^s{\cdot}9$. A
variations which have occurre
tion :—



Variation in Rotation period of the
the 68 years f

It has often been suggeste
years may be identic

"The ingenious Dr. Hooke did some months since intimate to a friend of his that he had, with an excellent 12-feet telescope, observed, some days before he then spoke of it (viz., on 1664 May 9 O.S.), about nine o'clock at night, a spot in the largest of the three obscure belts of *Jupiter*; and that, observing it from time to time, he found that, within two hours after, the said spot had moved east to west about half the length of the diameter. It is situated in the northern part of the southern belt. Its diameter is one-tenth of *Jupiter*; its centre, when nearest, is distant from that of *Jupiter* about one-third of the semi-diameter of the planet."

In the same volume of the *Phil. Trans.*, p. 60, appears the following:—

"*Hooke's Permanent Spot on Jupiter.*

"M. Cassini, after many observations during the summer of 1665, found that the period of its apparent rotation is $9^h\ 56^m$. He continued to observe this spot till the beginning of 1666, when *Jupiter* approached to the beams of the Sun; but after he had got out of them it was difficult to be discerned. But, 1672 January 19, N.S., observing *Jupiter* at $4\frac{3}{4}$ hours in the morning, he perceived in the same place of his disc the figure of the same spot adhering to the same southern belt. It had already gone over the half of this belt, and he saw it advance gradually towards the western limb, to which it seemed very near at $6\frac{1}{4}$ hours. By the celerity of its motion near the centre, and by the place when he had begun to see it, he judged it might have been in the middle of the belt at 4 hours and 35 minutes in the morning. And as he set about making ephemerides of its motion for 1672, he perceived that in those he made for 1666 this spot had been in the middle of *Jupiter* the same day, viz. January 19, at the same hour, so that in six years, of which one is a bissextile, it is found to have in respect of the Earth at least 5294 revolutions of $9^h\ 55^m\ 58^s$, one revolution with another, and at most 5295 revolutions of $9^h\ 55^m\ 51^s$, forasmuch as he was assured of the preciseness of one mean revolution to one-eighth of a minute. Till that time he never observed an immediate return of this spot after $9^h\ 56^m$, because that after the appearing of the spot *Jupiter* had not continued long enough above the horizon to observe him with due distinctness. But the night after March 1, at $7\frac{1}{2}$ hours in the evening, he saw this spot in the middle of the belt; and at $5^h\ 26^m$ in the following morning he saw it again return precisely to the same place." . . . "The next day" (vol. i. p. 706) "he made a report of these observations to the Royal Academy of Sciences, and predicted that the spot would arrive again at the midst of the belt on March 3 at 8 minutes after 9 o'clock; whereupon the assembly deputed M. Biot and M. Mariotte to be present at the observatory, who, being come to the Royal Observatory, began to see, at 4^m after 8 o'clock, the spot, already somewhat removed from the eastern limb, but yet

1672 January 19. Re de
end of 1674.
1677. Seen, but disappeai
1685 March. Re-observe
1687 October.
1690. Seen for a short tin
1691. Reappeared, but be
1694. Seen.
1708. Seen.
1713. Re-observed by Ma
this year.

It would be interesting to
Académie des Sciences and disc
tion period might thus be dete
of rate, for the fifty years from
Cassini's observations are to b
et Phisique, 1692 January.

From the date of Hooke's
March 19 (N.S.) to Cassini's ob
1666 January 19 (N.S.) I find
tions, with a corrected mean p
Cassini's observation in 1666 Jan
in 1672 January and March the
for from 5402 rotations the peri
the nine years from 1664 to 167
in a gradual manner, the annual
were probably as under :—

	h	m	s
1664	9	55	59
1665			58
1666			57
1667			56

tions, or at most 5295. The real number appears to have been 5294.

In 1713, according to J. P. Maraldi, the rate was $9^h\ 56^m$, so that the maxima occurred in about 1664 and 1713. If we adopt a cycle of $48\frac{1}{2}$ years as representing the changes, then maxima are also indicated for 1761, 1810, 1858, and 1907. This conforms very nearly with the slow rate observed for the red spot in 1859. It is also noteworthy that a period of about forty-eight years corresponds with the rapid motion of the spot exhibited in about 1831 (perhaps the minimum period really occurred in 1829, for which we have no observations), and 1877. These, however, are merely suggestions from insufficient data, the more complete investigation of old records would probably lead to more definite and certain conclusions.

In 1773, Jacques de Sylvabelle determined the period of a spot on *Jupiter* as $9^h\ 56^m$, but I am not aware whether this object offered any resemblance either in its form or position to Hooke's spot of 1664, or to the red spot of our own time. If the latter can be assumed to be identical with Hooke's spot of 1664 May 19, and the mean rate of rotation to have been $9^h\ 55^m\ 40^s$ during the long interval of $235\frac{1}{2}$ years to 1899 September 16, then the planet will have rotated 207,780 times since the spot was first discovered. The ancient marking is often called "Cassini's spot," though Cassini was certainly anticipated by Hooke, but the latter seems to have curiously neglected this feature and to have scarcely thought it worth mention. On the other hand, Cassini followed it with great perseverance, and derived some interesting conclusions from its apparition ; to him, therefore, belongs the most credit, and his name will always be closely associated with this interesting object.

In concluding, it may be mentioned that the supposed invisibility of the red spot in 1877 has sometimes been alluded to as a curious circumstance. When in opposition in June of that year the planet had a declination 23° S. of the equator, so it cannot be wondered at that this marking escaped observation in England. It was, however, seen at Sydney, N.S.W., by Mr. H. C. Russell, who writes me that, though during the summer of 1877 *Jupiter* was somewhat neglected in favour of *Mars*, the red spot was often observed. Its figure became so familiar that it was termed the "pink fish," it being somewhat fish shaped, the *p* end being round and the *f* end tapering. The observers having noticed its constancy in 1876 and 1877, regarded it as a permanent marking on the planet. Mr. Russell quotes one of his observations to the effect that on 1877 August 26, at 8 P.M. (local time), the "pink fish" was just passing off the planet's limb. In 1876 the spot was frequently seen, and appears on many of the drawings made at the Sydney Observatory in May, June, and July of that year. From Mr. Russell's descriptions of the position of the object relatively to the central meridian in the various drawings alluded to, its times of transit must have been approximately as follows :

These times are fairly consiste
nature of the estimates), exce
seems more than thirty minute

Bristol: 1899 September 21.

E

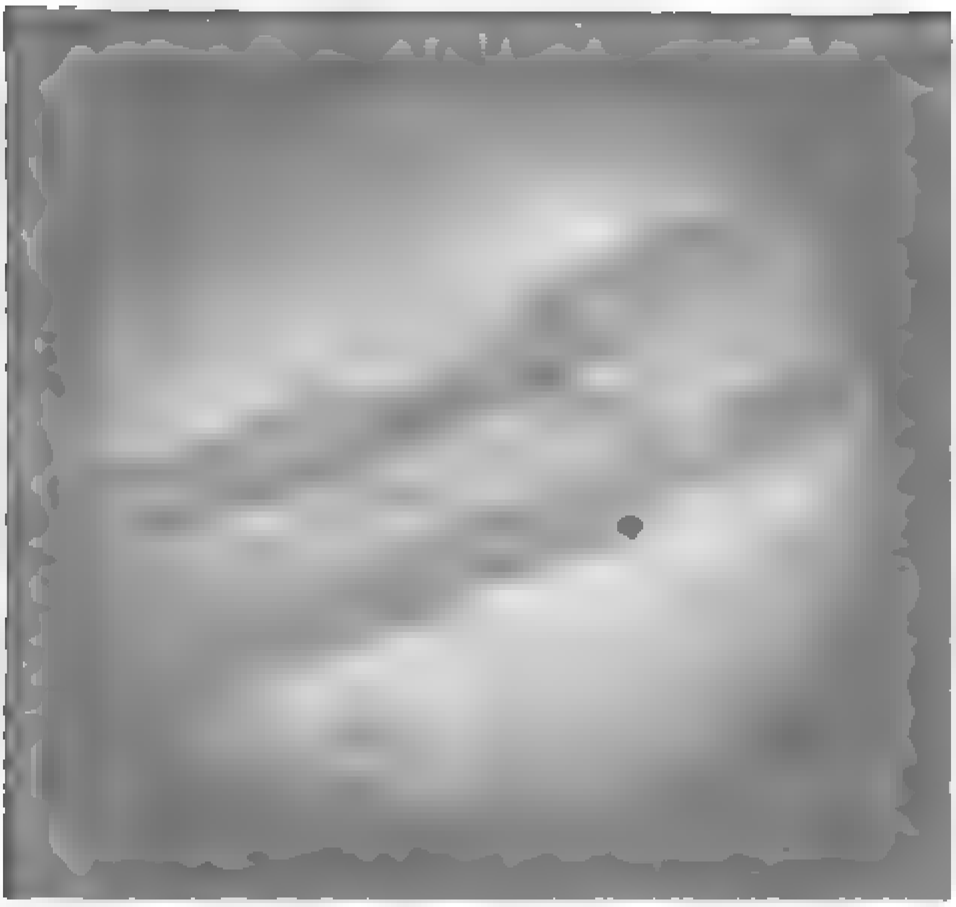
Monthly Notices, lviii. p. 484. Tl
should be 87 instead of 101, and for e
On p. 491 the number of rotations
is stated as 25,346. This is the obs
formed was 25,348 and about one-thir

Note on the Motion of Jupiter's

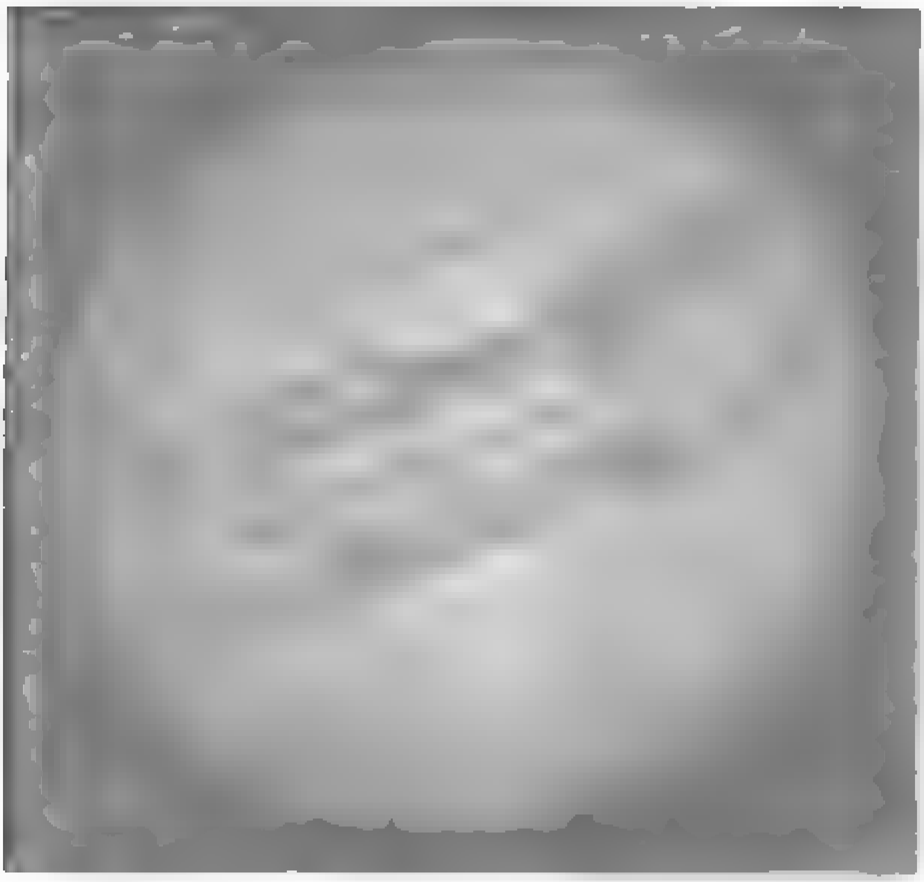
The slackening motion of t
accordance with the forecast g
meris to the effect that it wou
System II. by about 52^{m} at th
(1898 December 10), and abou
September 18).

A considerable number of t
over the central meridian of *Jup*
during the present apparition. (
attenuation of the spot's intensi
culty of the observations, the est
refer to the centre of the red spot
in which it is located.

On 1899 May 30 the follow
Antoniadi :—



6.



DRAWINGS OF JUPITER MADE AT JUVISY, FRANCE

[illegible]

[illegible] the [illegible] ting [illegible] must [illegible] to the [illegible]

On [illegible] the following [illegible]

MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY VOL. LIX., PLATE 1

$\lambda = 34^{\circ}\!\cdot 1.$ $\phi = 3^{\circ}\!\cdot 1.$

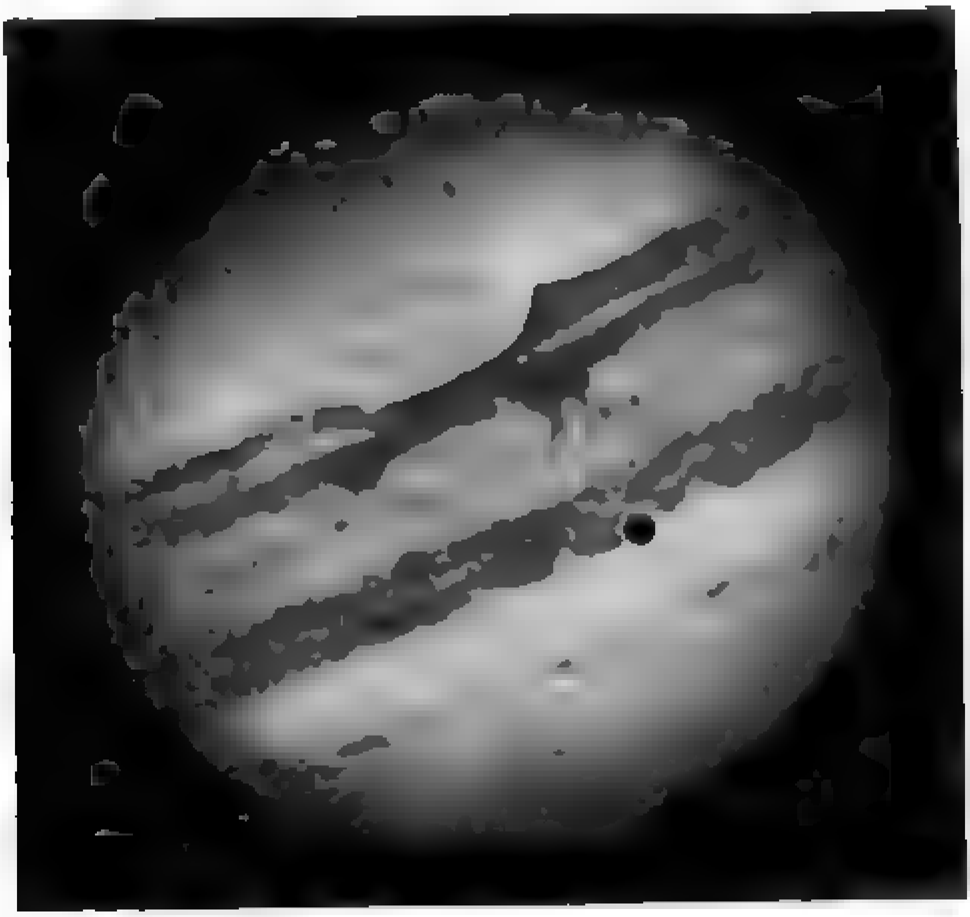


FIG. 1.—1899 MAY 30^d 10^h 9.5^m G.M.T.
(E. M. ANTONIADI.)

$\lambda = 23^{\circ}\!\cdot 6.$ $\phi = -3^{\circ}\!\cdot 1.$

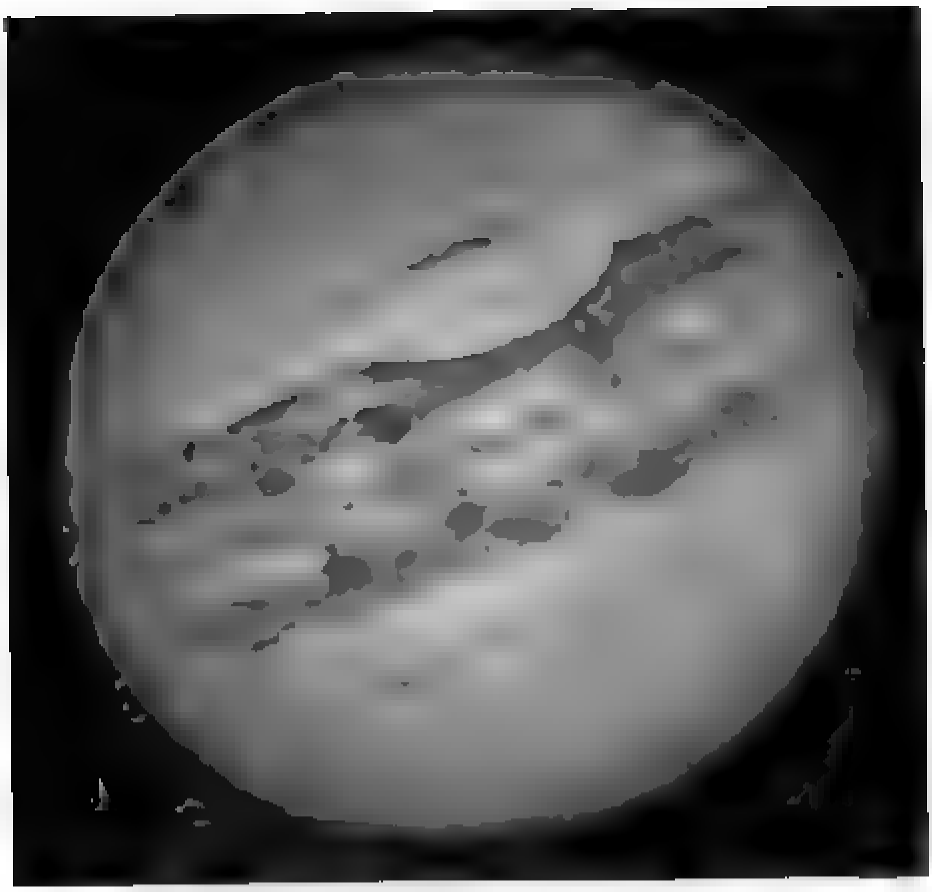


FIG. 2.—1899 JUNE 4^d 9^h 0^m.
(C. FLAMMARION.)

DRAWINGS OF JUPITER MADE AT JUVISY, FRANCE.

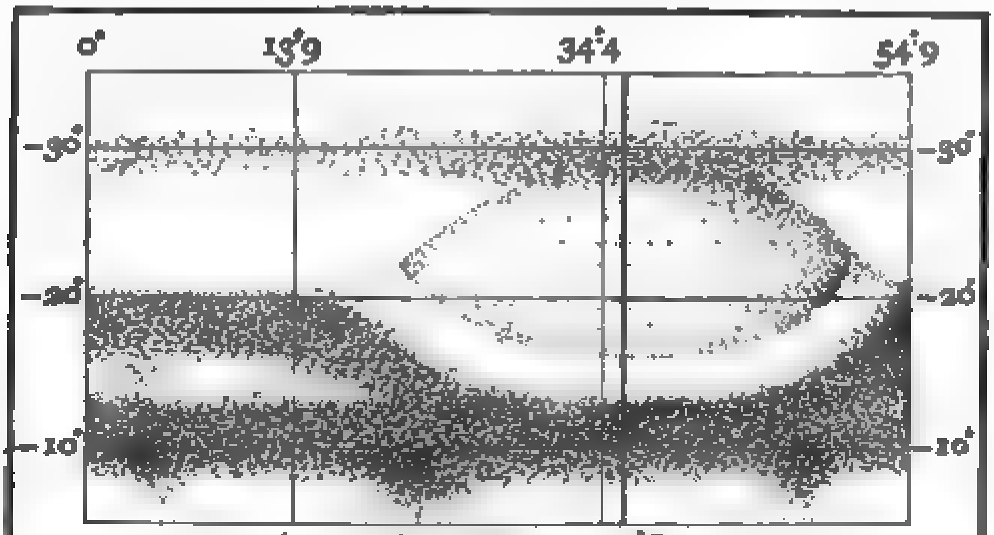
As the zero-meridian of System II. was central at $9^h\ 13^m{\cdot}0$, it follows that the centre of the bay was $56^m{\cdot}5$ late on May 30, which corresponds to $\lambda = 34°\ 1$.

Five days later, on June 4, I was enabled to make the following observations:—

	h m
Passage of *p* shoulder	8 44 G.M.T.
Passage of centre of cavity	9 18
Passage of *f* shoulder	9 52

The zero-meridian being central at $8^h\ 21^m{\cdot}1$ on June 4, we have for the longitude of the middle of the bay the value of $56^m{\cdot}9 = 34°{\cdot}4$. Fig 2 of the accompanying plate (plate 10) was taken some eighteen minutes before the passage of the Red Spot

The observations of Mr. Denning * and Rev. T. E. R. Phillips have shown that the spot is not quite central in the great bay, being somewhat nearer to the *f* elbow. Now, as our recent impressions confirm this view, $59^m \pm = 35°{\cdot}8 \pm$ might be considered as a more probable value of the spot's longitude on June 4 than $56^m{\cdot}9 = 34°{\cdot}4$. The subjoined map of the Red Spot region resumes my impressions at the latter date.



Longitude (System II) of 'Red' Spot = 35°8 ± (*1899, June 4*)

Inasmuch as *Jupiter* is showing us at the present apparition his south pole, the belts are not straight, but curved, being concave to the south, as drawn by Mr. Stanley Williams in his *Zenographical Fragments*, twelve years ago. I should also like to confirm Mr. Williams's statement that "both belts are of a moderately deep red colour, and are [now] nearly equally red, though the south equatorial belt usually appears distinctly a little redder than the north equatorial belt."†

* *Monthly Notices*, vol. lviii. No. 9.

† *Ibid.* vol. lix. No. 7. The belts appeared to me fainter at this apparition than during the last few years.

Juvisy Observatory (S.-et-O.), France,
1899 *June* 20.

Further Notes on Saturn's "Crape" Ring. By E. M. Antoniadi.

The paper on pp. 498–501 has shown the hypothesis of a dark ring round *Saturn* to be unnecessary; indeed, the phenomena seem only explicable by the assumption of a bright ring. We thus reach the generalisation that the albedo of the individual particles is very likely the same in *all* parts of the ring system, and that brightness here is a function of aggregation.

The remarkable appearances which were observed by Dawes half a century ago, and which led him to consider the figure generating this ring to be "somewhat wedge-shaped," have been shown to be rational consequences of the interpretation in question; but the differences between the heights of the Sun and Earth above the plane of the ring have not been ascribed at first by the writer to their ordinary and most effective cause, which is the motion of the Earth in her orbit.

When Dawes wrote that the projection of the dark ring at its minor axis was "considerably narrower than accords with its breadth at the major axis," the difference in altitude of the Sun and Earth above the ring was very considerable, as will be seen from the following data, taken from the *Nautical Almanac* of 1850 and 1851, and for which the writer is indebted to the kindness of M. Fraissinet, Secretary to the National Observatory, Paris. The height of the Sun above the plane of the ring is here designed by a, that of the Earth by b, while Δ stands for the difference of these two values :—

Date.	a	b	Δ
	° ′	° ′	° ′
1850 November 17	11 56·0 S	10 5·9 S	1 50·1
„ December 27	12 30·1	9 57·2	2 32·9
1851 January 1	12 34·0	10 1·1	2 32·9
„ February 10	13 7·8	11 11·4	1 56·4

A letter of Dawes', dated 1852 November 29,* mentions that "in the beginning of 1851 the difference" [narrowness of "dark" ring across the globe] "appeared much greater than it now does." These words give us an opportunity to submit our theory to a crucial test, for, if correct, it would necessitate a smaller value of Δ for 1852 November than for 1850 December 1851 January. Checking our deduction by the ephemeris given in the *Nautical Almanac*, we find it verified to the letter :—

Date.	a	b	Δ
	° ′	° ′	° ′
1852 August 28	20 19·2 S	21 52·2 S	1 33·0
„ October 7	20 45·4	21 26·0	−0 40·6
„ November 16	21 11·0	20 36·1	0 34·9
„ „ 29†	21 19 ±	20 25 ±	0 54 ±
„ December 26	21 35·9	20 2·6	1 33·3

* *Monthly Notices*, vol. xiii. 1852 Nov. 12, p. 20.

† Value found approximately by interpolation.

We thus have the inequality

$$0^\circ\ 54' < 2^\circ\ 32'{\cdot}9,$$

which shows that the difference in altitude of the Sun and Earth above the plane of the rings was smaller in November 1852 than in January 1851.

But the differences in altitude of the Sun and Earth above the plane of the rings do not solely affect the breadth of the "crape" ring's shadow about the lesser axis; they also disfigure its outline, by deviating it from concentricity with the apparent ellipses of the system. Neglecting the departure from centrality resulting from the position of *Saturn* in quadrature, we may state :—

(*a*) That with a Sun higher than the Earth, the shadow's breadth would be particularly reduced about the planet's limbs; while

(*b*) With a Sun lower than the Earth, its maximum breadth would, on the contrary, occur about the limbs.

Of these two appearances, the second is not a very unfrequent one,* but nothing like the former has ever been drawn, to the writer's knowledge. How, then, are we to account for the failure? We might, in reply, first point to the fact that the difference in length of the radii of the planet and the inner edge of the "dark" ring is not excessive, and that consequently the deformation could never be too marked either. This, however, does not suffice, and we may readily anticipate the action of optical phenomena. Irradiation, which is most active about the centre of *Saturn*, in reducing the breadth of the dusky shadow, must atone to some extent for the deformity, while the darkness of the planet's limb, in which the dusky projection shades off rather gently, might also act in the same direction.

We know from the investigations of Edouard Roche that the rings are composed of particles so small that the tide-generating force of the primary is absolutely powerless on them. Considered in connection with the fact that the Sun viewed from *Saturn* is not a point, but a very appreciable disc, this statement leads us to the conclusion that the modicum of shadow cast on the planet by each individual particle is not black, but penumbral † only,

* Under a large opening of the system the form (*b*) is often seen, even when the Sun and Earth have the same altitude above the plane of the ring. The phenomenon must, then, be due to the interference of the dark equatorial belt, on which the "crape" ring is projected.

† The writer's attention was recently drawn to the penumbral nature of the "crape" ring's shadow by a letter from Mr. Stanley Williams, in which it is said that, "Probably, if the particles composing the ring are very small, no actual black shadows would fall on the globe, but only penumbral shades, though the effect would be just the same." This quality of the shadow was also independently suspected by the writer three years previously, when he spoke of "the (*penumbral*) shadow on the planet of these same particles" (*Journal of the British Astronomical Association*, vol. vii. No. 5, p. 242).

Midnight.	Colong.	Lat.
	of the Sun.	
1900.	°	°
Jan. 1	279·06	+0·59
2	291·26	+0·61
3	303·44	+0·64
4	315·62	+0·66
5	327·80	+0·69
6	339·97	+0·71
7	352·13	+0·74
8	4·28	+0·76
9	16·43	+0·79
10	28·58	+0·82
11	40·71	+0·85
12	52·85	+0·87
13	64·98	+0·90
14	77·12	+0·92
15	89·25	+0·95
16	101·38	+0·98
17	113·52	+1·00
18	125·65	+1·02
19	137·79	+1·05
20	149·94	+1·07
21	162·09	+1·09
22	174·24	+1·11
23	186·40	+1·13
24	198·56	+1·14
25	210·73	+1·16
26	222·00	+1·18

Greenwich Midnight. 1900.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
		°	°	°	°	°	°
Jan.	30	271·66	+1·24	−2·53	−5·14	5·73	153·8
	31	283·86	+1·25	−0·51	−6·04	6·06	175·2
Feb.	1	296·05	+1·26	+1·54	−6·52	6·70	193·3
	2	308·24	+1·28	+3·43	−6·54	7·38	207·7
	3	320·43	+1·30	+5·01	−6·12	7·90	219·3
	4	332·61	+1·31	+6·19	−5·33	8·16	229·3
	5	344·78	+1·33	+6·91	−4·23	8·10	238·5
	6	356·94	+1·35	+7·20	−2·93	7·77	247·9
	7	9·10	+1·36	+7·09	−1·50	7·24	258·1
	8	21·25	+1·38	+6·65	−0·04	6·65	269·6
	9	33·40	+1·40	+5·95	+1·40	6·11	283·2
	10	45·54	+1·41	+5·06	+2·75	5·76	298·5
	11	57·69	+1·43	+4·03	+3·95	5·64	314·4
	12	69·83	+1·44	+2·90	+4·97	5·76	329·7
	13	81·97	+1·45	+1·70	+5·76	6·00	343·6
	14	94·11	+1·46	+0·47	+6·29	6·31	355·7
	15	106·25	+1·47	−0·80	+6·54	6·58	7·0
	16	118·39	+1·48	−2·07	+6·52	6·84	17·6
	17	130·54	+1·49	−3·33	+6·21	7·05	28·2
	18	142·69	+1·50	−4·55	+5·63	7·23	38·9
	19	154·84	+1·50	−5·67	+4·80	7·43	49·7
	20	167·00	+1·51	−6·65	+3·74	7·64	60·6
	21	179·16	+1·51	−7·40	+2·48	7·81	71·5
	22	191·33	+1·52	−7·85	+1·07	7·92	82·2
	23	203·51	+1·52	−7·92	−0·44	7·94	93·2
	24	215·69	+1·52	−7·54	−1·97	7·79	104·6
	25	227·88	+1·52	−6·66	−3·43	7·49	117·2
	26	240·08	+1·53	−5·28	−4·72	7·08	131·8
	27	252·28	+1·53	−3·47	−5·72	6·69	148·8
	28	264·49	+1·53	−1·36	−6·33	6·48	167·9
Mar.	1	276·69	+1·53	+0·87	−6·49	6·55	187·6
	2	288·90	+1·53	+3·01	−6·19	6·88	205·9
	3	301·10	+1·54	+4·85	−5·46	7·30	221·6
	4	313·30	+1·54	+6·27	−4·38	7·64	235·1
	5	325·49	+1·54	+7·18	−3·07	7·80	246·9
	6	337·68	+1·55	+7·59	−1·62	7·75	258·0
	7	349·86	+1·55	+7·53	−0·13	7·53	269·0
	8	2·04	+1·55	+7·08	+1·33	7·20	280·6

Greenwich Midnight. 1900.	Selenographical Colong. of the Sun	Lat.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.
March 9	14·21	+1·55	+6·32	+2·69	6·87	293·1
10	26·37	+1·55	+5·33	+3·89	6·60	306·1
11	38·53	+1·55	+4·19	+4·91	6·46	319·5
12	50·69	+1·55	+2·96	+5·70	6·42	332·6
13	62·85	+1·55	+1·69	+6·24	6·46	344·8
14	75·01	+1·55	+0·40	+6·51	6·52	356·5
15	87·16	+1·54	−0·86	+6·50	6·56	7·5
16	99·32	+1·54	−2·09	+6·21	6·55	18·6
17	111·48	+1·53	3·28	+5·64	6·52	30·2
18	123·63	+1·52	−4·39	+4·82	6·52	42·3
19	135·79	+1·51	−5·41	+3·77	6·60	55·1
20	147·95	+1·50	−6·29	+2·53	6·78	68·1
21	160·12	+1·49	−6·99	+1·15	7·08	80·7
22	172·30	+1·48	−7·43	−0·32	7·44	92·5
23	184·48	+1·47	−7·55	−1·80	7·76	103·4
24	196·66	+1·46	−7·28	−3·23	7·97	113·9
25	208·86	+1·45	−6·57	−4·51	7·96	124·0
26	221·06	+1·44	−5·40	−5·55	7·74	135·8
27	233·27	+1·42	−3·83	−6·25	7·33	158·5
28	245·49	+1·41	−1·92	−6·54	6·81	163·6
29	257·71	+1·40	+0·15	−6·37	6·37	181·3
30	269·93	+1·39	+2·20	−5·75	6·15	200·9
31	282·15	+1·38	+4·05	−4·75	6·25	220·5
April 1	294·37	+1·37	+5·53	−3·43	6·51	238·2
2	306·59	+1·36	+6·57	1·94	6·85	253·6
3	318·80	+1·35	+7·11	−0·38	7·12	266·0
4	331·01	+1·34	+7·17	+1·16	7·26	279·2
5	343·21	+1·33	+6·82	+2·59	7·30	290·8
6	355·41	+1·32	+6·13	+3·85	7·23	302·1
7	7·60	+1·31	+5·17	+4·91	7·13	313·5
8	19·78	+1·29	+4·03	+5·74	7·01	324·9
9	31·96	+1·28	+2·78	+6·31	6·90	336·2
10	44·14	+1·26	+1·49	+6·60	6·76	347·3
11	56·32	+1·24	+0·21	+6·62	6·62	358·2
12	68·49	+1·23	1·03	+6·35	6·44	9·2
13	80·66	+1·21	2·19	+5·79	6·19	20·7
14	92·83	+1·19	3·25	+4·98	5·95	33·1
15	105·00	+1·17	−4·20	+3·93	5·75	46·0

Greenwich Midnight.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
1900.		°	°	°	°	°	°
April	16	117·17	+1·14	−5·01	+2·68	5·68	61·9
	17	129·34	+1·12	−5·67	+1·28	5·81	77·3
	18	141·52	+1·10	−6·15	−0·20	6·16	91·9
	19	153·70	+1·08	−6·40	−1·70	6·62	104·9
	20	165·89	+1·05	−6·39	−3·14	7·12	116·2
	21	178·09	+1·03	−6·07	−4·43	7·51	126·1
	22	190·29	+1·01	−5·43	−5·50	7·72	135·4
	23	202·49	+0·99	−4·44	−6·26	7·67	144·7
	24	214·71	+0·97	−3·13	−6·64	7·34	154·8
	25	226·93	+0·94	−1·58	−6·59	6·78	166·5
	26	239·17	+0·92	+0·11	−6·11	6·11	181·0
	27	251·40	+0·90	+1·80	−5·21	5·51	199·1
	28	263·64	+0·88	+3·36	−3·97	5·20	220·2
	29	275·88	+0·87	+4·66	−2·49	5·28	241·9
	30	288·12	+0·85	+5·60	−0·88	5·67	261·1
May	1	300·35	+0·83	+6·14	+0·73	6·18	276·8
	2	312·58	+0·81	+6·25	+2·27	6·66	289·9
	3	324·81	+0·79	+5·99	+3·64	7·01	301·3
	4	337·03	+0·77	+5·38	+4·79	7·20	311·7
	5	349·24	+0·75	+4·49	+5·70	7·25	321·8
	6	1·45	+0·72	+3·41	+6·35	7·21	331·8
	7	13·66	+0·70	+2·19	+6·70	7·04	341·9
	8	25·86	+0·67	+0·93	+6·77	6·83	352·2
	9	38·05	+0·65	−0·34	+6·55	6·56	3·0
	10	50·25	+0·62	−1·53	+6·05	6·24	14·2
	11	62·44	+0·60	−2·61	+5·27	5·88	26·4
	12	74·62	+0·57	−3·54	+4·25	5·53	39·8
	13	86·81	+0·54	−4·30	+3·01	5·25	55·0
	14	98·99	+0·51	−4·86	+1·60	5·11	71·8
	15	111·18	+0·48	−5·21	+0·09	5·21	89·0
	16	123·36	+0·45	−5·34	−1·46	5·54	105·3
	17	135·55	+0·42	−5·23	−2·94	6·00	119·3
	18	147·74	+0·39	−4·91	−4·29	6·53	131·2
	19	159·94	+0·36	−4·34	−5·42	6·94	141·3
	20	172·14	+0·34	−3·57	−6·23	7·17	150·2
	21	184·35	+0·31	−2·60	−6·69	7·17	158·8
	22	196·57	+0·28	−1·47	−6·74	6·89	167·7
	23	208·80	+0·26	−0·24	−6·37	6·38	177·8

Greenwich Midnight. 1900.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
		°	°	°	°	°	°
May	24	221.03	+0.23	+1.03	−5.59	5.70	190.4
	25	233.27	+0.21	+2.25	−4.46	5.00	206.8
	26	245.52	+0.19	+3.35	−3.06	4.54	227.6
	27	257.76	+0.16	+4.25	−1.49	4.50	250.7
	28	270.01	+0.14	+4.90	+0.15	4.90	271.8
	29	282.26	+0.12	+5.24	+1.74	5.52	288.4
	30	294.51	+0.09	+5.26	+3.21	6.16	301.4
	31	306.75	+0.07	+4.96	+4.47	6.68	312.0
June	1	318.99	+0.04	+4.37	+5.49	7.02	321.5
	2	331.23	+0.02	+3.52	+6.23	7.16	330.5
	3	343.46	−0.01	+2.47	+6.68	7.12	339.7
	4	355.68	−0.03	+1.29	+6.83	6.95	349.3
	5	7.90	−0.06	+0.04	+6.69	6.69	359.7
	6	20.11	−0.09	−1.21	+6.27	6.39	10.9
	7	32.32	−0.12	−2.38	+5.57	6.05	25.1
	8	44.53	−0.15	−3.42	+4.61	5.74	36.6
	9	56.73	−0.18	−4.26	+3.43	5.47	51.2
	10	68.93	−0.21	−4.86	+2.06	5.27	67.0
	11	81.12	−0.24	−5.17	+0.56	5.20	83.8
	12	93.31	0.26	5.20	−1.01	5.30	101.0
	13	105.50	−0.29	−4.93	−2.55	5.55	117.4
	14	117.69	−0.32	−4.38	−3.97	5.91	132.2
	15	129.88	−0.35	−3.60	−5.17	6.29	145.2
	16	142.07	−0.38	−2.64	−6.08	6.63	150.5
	17	154.27	0.41	−1.50	−6.62	6.81	160.7
	18	166.48	−0.44	−0.44	−6.75	6.76	1[illegible]6.3
	19	178.70	−0.46	+0.68	−6.46	6.50	186.0
	20	190.92	−0.48	+1.74	5.78	6.04	196.8
	21	203.16	−0.51	+2.68	−4.75	5.45	209.4
	22	215.39	−0.53	+3.48	−3.44	4.89	225.3
	23	227.64	−0.55	+4.12	−1.95	4.55	244.7
	24	239.89	−0.57	+4.57	−0.36	4.58	265.5
	25	252.14	−0.59	+4.81	+1.23	4.96	284.3
	26	264.39	−0.61	+4.83	+2.72	5.54	200.4
	27	276.64	0.63	+4.61	+4.04	6.13	311.2
	28	288.90	−0.66	+4.16	+5.14	6.61	321.0
	29	301.15	−0.68	+3.49	+5.97	6.90	329.7
	30	313.39	−0.70	+2.60	+6.51	7.01	338.2
July	1	325.64	0.72	+1.54	+6.74	6.91	347.1

The longitudes are reckoned in the plane of the Moon's equator, the axis of reference being the radius which passes through the mean centre of the visible disc. This axis therefore rotates with the Moon, and is not fixed in space.

The inclination of the Moon's equator to the ecliptic is taken as $1°\cdot523$, the value used in the *Connaissance des Temps*, that given by the *Nautical Almanac* being $1°\cdot536$.

I have taken the value of the physical libration in longitude from the *Berliner Jahrbuch* for the days on which it is tabulated there, the values on intermediate days being found by a graphical method. In other words, the whole of Professor Franz's formula for the physical libration has been used, instead of the principal term alone, as heretofore.

The physical libration in latitude has been applied in the above ephemeris for the first time, its value being likewise taken from the *Berliner Jahrbuch.* But in each case the sign of the libration as given in the *Jahrbuch* requires to be changed to reduce it to the system used here. Some doubts having been expressed to me as to whether the physical libration has hitherto been applied with the correct sign, I consulted Professor Franz, who replied that the sign heretofore used was correct, and that the sign of the physical libration in the *Berliner Jahrbuch* requires to be reversed both in longitude and latitude, in order to reduce it to the system used in the above ephemeris.

The colongitude of the Sun is 90° (or 450°) *minus* his selenographical longitude. It also is the selenographical longitude of the morning terminator reckoned eastward from the mean centre of the disc. Hence its value is approximately 270°, 0°, 90°, 180° at new Moon, first quarter, full Moon, last quarter respectively. The longitude of the evening terminator is of course 180° greater or less than that of the morning one.

When the geocentric libration in longitude is positive, the region brought into view is on the west limb; when negative, on the east.

When the geocentric libration in latitude is positive, the region brought into view is at the Moon's north pole; when negative, at the south.

The column "Combined Amount" gives the distance between the apparent and mean centres of the disc, and the column "Direction" gives the position-angle of the apparent centre from the mean centre, or, which is the same thing, the position-angle of the region which is most carried into view by libration. The angles are reckoned eastward from the northern extremity of the Moon's axis.

The terms "East" and "West" are used throughout with reference to our sky, and not as they would appear to an observer on the Moon.

Benvenue, 55 *Ulundi Road, Blackheath, S.E.:*
1899 *September* 30.

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PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
LONDON

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AND OF

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JUNE 1898 TO JUNE 1899.

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PHOTOGRAPHS PRESENTED TO THE SOCIETY.

Burckhalter (C.) Photographs of the total solar eclipse of 1898 January 22, taken with a telescope of 15 feet focal length and revolving shutter (two prints from the same negative).

Muybridge (E.)—Seven photographs of the partial solar eclipse 1880 January 11, made at Palo Alto, California (enlarged positives on glass).

Newbegin (G. J.)—Series of photographs of the Sun (original negatives), 1898 September-November.

Salmon (S. H. R.)—Six photographs of artificial lunar formations (lantern slides).

Souillart (Madame)—Portrait of Prof. C. Souillart.

Wolf (Max).—Photographs of fields of stars showing trails of minor Planets, and of the lunar eclipse, 1898 December 27

ROYAL ASTRONOMICAL SOCIETY.

LIST OF FELLOWS AND ASSOCIATES.

JUNE 1899.

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OF THE

ROYAL ASTRONOMICAL SOCIETY.

FEBRUARY 1899 TO FEBRUARY 1900.

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Vice-Presidents.

Capt. W. DE W. ABNEY, C.B. R.E. D.C.L. F.R.S.
Sir R. S. BALL, M.A. LL.D. F.R.S. Lowndean Professor of Astronomy and Geometry, Cambridge.
W. H. M. CHRISTIE, Esq. C.B. M.A. F.R.S. Astronomer Royal.
J. W. L. GLAISHER, Esq. M.A. Sc.D. F.R.S.

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E. B. KNOBEL, Esq.

Secretaries.

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H. F. NEWALL, Esq. M.A.

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G. M. SEABROKE, Esq.
W. G. THACKERAY, Esq.
H. H. TURNER, Esq. M.A. B.Sc. F.R.S. Savilian Professor of Astronomy, Oxford.

Assistant Secretary.

Mr. W. H. WESLEY.

BURLINGTON HOUSE,
LONDON, W.

The Meetings are held on the second Friday in every month during the Sessic at 8 o'clock P.M., except the Annual General Meeting in February, which is held 3 o'clock in the afternoon.

LIST OF THE FELLOWS

OF THE

ROYAL ASTRONOMICAL SOCIETY,

JUNE 1899.

An asterisk (*) prefixed to a name indicates that the member has compounded for his Annual Contributions.

Should any errors or omissions be found in this List, it is requested that notice thereof be given to the Assistant Secretary.

PATRON:

HER MAJESTY QUEEN VICTORIA.

The present addresses of the following Fellows are not known, and the Secretaries would be glad of any information which would enable them to be traced:

	LAST KNOWN ADDRESS.
Robert John Baillie ...	**Grosvenor House, Carlisle. (1899 April.)**
***J. Owen Corrie ... ...**	**131 Denmark Terrace, Brighton. (1896 June.)**
***Isaac Engelson ... ...**	**Pomme d'Or, Jersey. (1897 Nov.)**
Capt. J. Fisher	**Kentmere, Birdhurst Rise, South Croydon. (1897 Nov.)**
Rev. James H. Honeyburne,	**70 Devonshire Road, Princes Park, Liverpool. (1898 Dec.)**
Louis J. W. Joyner ...	**72nd Street, New York City. (1899 April.)**
George Kilgour, M.Inst.C.E.	**F.R.G.S. F.G.S., Cape Town. (1896 April.)**
***D. Lindsay Lowson ...**	**164 Kennington Road, S.E. (1883 June.)**

Australia.

1854 Mar. 10	Joseph Supino	Ancona, *Fernleigh, South Norwood, S.E.*
1896 Apr. 10	William	Anderson, *Quinta da Grevillea, Rua das Hortas, Funchal, Madeira.*

LIST OF THE FELLOWS

OF THE

ROYAL ASTRONOMICAL SOCIETY,

JUNE 1899.

An asterisk (*) prefixed to a name indicates that the member has compounded for his Annual Contributions.

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PATRON:

HER MAJESTY QUEEN VICTORIA.

FELLOWS.

Date of Election.	
1876 Jan. 14	* Prof. Cleveland Abbe, *Weather Bureau, Department of Agriculture, Washington, D.C., U.S.A.*
1870 Apr. 8	Capt. W. DE W. ABNEY, C.B. R.E. D.C.L. F.R.S., VICE-PRESIDENT, PAST PRESIDENT, *Rathmore Lodge, Bolton Gardens South, S.W.*
1883 Mar. 9	* Rev. E. Aurelius Adams, M.A., 10 *Hove Park Villas, Brighton.*
1893 Feb. 10	Harold John Adams, M.A., *St. John's, Cedars Road, Beckenham, S.E.*
1893 Mar. 10	Maur. Anderson Ainslie, R.N. B.A., *The Liberty, Wells, Somerset.*
1896 Jan. 10	* Hugh Lancelot Aldis, 49 *Hartismere Road, Fulham, S.W.*
1885 Mar. 13	* Wm. Steadman Aldis, M.A., *Kidlington, near Oxford.*
1880 Nov. 12	* Rev. Francis B. Allison, M.A., *The Vicarage, Peasmarsh, Sussex.*
1867 Nov. 8	Thomas Michael Almond, Port Master, *Brisbane, Queensland, Australia.*
1854 Mar. 10	Joseph Supino Ancona, *Fernleigh, South Norwood, S.E.*
1896 Apr. 10	William Anderson, *Quinta da Grevillea, Rua das Hortas, Funchal, Madeira.*

1888 Feb. 10		Rev. J Mackenzie Bacon
1892 June 10		Rev James Baiki
		sh
1877 Jan. 12		Robert John Bailli
1875 Mar. 12	*	Sir ROBT. STAWELL BA
		of
		sit
		Pr
1898 May 13		George Banas
1896 May 8		William Banks,
		Bo
1884 Nov. 14		Pietro Baracc
		Me
1895 Feb. 8		Edwin Bare,
		ston
1893 Feb. 10		Samuel Barker,
1874 May 8	*	Rev. H. Glanville Barnacl
		Pre
1888 Jan. 13	*	Edward Emerson Barnarc
		Bay
1879 May 9		Capt. Edward Barnes,
1899 Apr. 14		Ernest William Barnes,
1881 May 13	*	John Alfred Barring
		Leed.
1863 Nov. 13		Rev. J. Chadwick Bates,
		cheste
1880 Apr. 9	*	Maj. T. Preston Battersb
		R.A.)
		land,
1895 Feb. 8		Comte Aymar de la Bau
		Paris
1892 May 13		Henry Baynham
		Ferns

Date of Election.		
1893 June 9	Hedley Robert	Beasley, 10 *Shear Bank Road;* and *Grammar School, Blackburn, Lancashire.*
1877 May 11	* William Morris	Beaufort, F.R.G.S., 18 *Piccadilly, W.;* and *Athenæum Club, S.W.*
1893 Apr. 14	Ludwig	Becker, Ph.D. F.R.S.E., Professor of Astronomy in the University of Glasgow, *Observatory, Glasgow.*
1862 Apr. 11	Commr. James F.	Beckett, R.N., *Avondell, Hollington Park, St. Leonard's-on-Sea.*
1896 Feb. 14	Frank Arthur	Bellamy, F.R.Met.Soc., *University Observatory;* and 4 *St. John's Road, Oxford.*
1892 Feb. 12	Bertram	Bennett, M.A., *Montpelier, Paignton, South Devon.*
1888 Mar. 9	* Arthur	Berry, M.A., *King's College, Cambridge.*
1893 Jan. 13	Joseph Ibbitson	Berry, *Hazeldene, Avenue Road, Highgate, N.*
1899 May 12	Rev. Edwd. Lyon	Berthon, M.A., *St. Margaret's, Cupernham, Romsey, Hants.*
1866 Nov. 9	* Rev. Frank	Besant, M.A., *Sibsey Vicarage, Boston, Lincolnshire.*
1854 Feb. 10	* Wm. Henry	Besant, M.A. Sc.D. F.R.S., *St. John's College, Cambridge.*
1890 Jan. 10	Algernon Sidney	Bicknell, 23 *Onslow Gardens, S.W.*
1869 Jan. 8	* Lieut.-Col. A. C.	Bigg-Wither, *Tilthams, Godalming, Surrey.*
1881 Jan. 14	Raphael Louis	Bischoffsheim, *Observatoire, Nice;* and 3 *Rue Taitbout, Paris.*
1875 Apr. 9	Lord	Blythswood, *Blythswood, near Renfrew, Scotland;* and 2 *Seamore Place, Curzon Street, W.*
1894 Apr. 13	Lyndon	Bolton, B.A., *Patent Office, Southampton Buildings, Chancery Lane, W.C.*
1888 Nov. 9	Thomas	Bolton, *Chowringhee, Wembley, N.W.*
1894 Dec. 14	George Cox	Bompas, F.G.S. F.R.G.S., 121 *Westbourne Terrace, W.*
1887 Apr. 6	Rev. John	Bone, *St. Thomas's Vicarage, Lancaster.*
1871 Nov. 10	* Robt. Holford M.	Bosanquet, M.A. F.R.S., *Castillo Zamora, Realejo Alto, Teneriffe, Canary Islands.*
1889 Jan. 11	* Henry Lord	Boulton, *Carácas, Venezuela, South America.*
1895 Feb. 8	Vincent Joseph	Bouton, B.Sc., 9 *Lansdowne Terrace, Hampton Wick.*
1867 Feb. 8	* Edward E.	Bowen, *Harrow School, Harrow-on-the-Hill.*
1892 Dec. 9	John A.	Brashear, *Allegheny, Pennsylvania, U.S.A.*
1893 Jan. 13	Martin	Brendel, Ph.D., Professor of Theoretical Astronomy and Geodesy in the University, 42 *Bühlstrasse, Göttingen, Germany.*
1871 June 9	John	Brett, A.R.A., *Daisyfield, Putney Heath Lane, S.W.*

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1888 Feb. 10	*	John Henry	Brow
1891 Jan. 9	*	James Stark	Brow
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1894 May 11		Rev. Saml. Robert	Brow
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1890 May 9		Thomas William	Brow
1865 Mar. 10		John	Brown
1887 Dec. 9		Hon. Justice Gainsford	B
1882 Nov. 10	*	Robert	Bryan
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1892 Dec. 9	*	Walter William	Bryant
			18
1894 Jan. 12		John Harrison	Buckle
1880 May 14		Thomas	Buckne
1896 June 12		Rev. Fredk. Lisle	Bullen,
1892 Feb. 12		Charles	Burckh
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1890 Jan. 10		Rev. George	Burges
			New
1897 Apr. 9		Rev. Sherrard B.	Burnab
1874 Nov. 13	*	Sherburne W.	Burnha
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1885 Apr. 10	*	Major Sidney G	Burrar
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Date of Election.			
1865 Apr. 12	*	Col. Alexander	Burton-Brown, R.A. F.G.S., 11 *Union Crescent, Margate.*
1873 Nov. 14		Thomas Wm.	Bush, *care of Rev. G. W. Allen,* 1 *Borrage Terrace, Ripon.*
1871 May 12	*	Reginald	Bushell, *Hinderton Lodge, Neston, Cheshire.*
1887 Apr. 10	*	Warren Fredk.	Caborne, C.B. Commander R.N.R. F.R.G.S. F.R.Met.Soc., *Claremont,* 54 *Alexandra Road, Upper Norwood, S.E.*
1877 June 8	*	George	Calver, *Hill House, Widford, Chelmsford.*
1867 Feb. 8		James	Carpenter, *Grove House, Lewisham, S.E.*
1889 May 10	*	Edward	Carpmael, B.A. Assoc. Inst. C.E., *The Ivies, St. Julian's Farm Road, West Norwood, S.E.*
1873 Feb. 14	*	Ernest	Carpmael, M.A., *Ferndale, Woodside Road, Sutton, Surrey.*
1891 Jan. 9		Edward Tremlett	Carter, Assoc. Inst. E.E., 53 *Cloudesdale Road, Upper Tooting, S.W.*
1896 Mar. 13	*	James	Cavan, M.A., *Eaton Mascott Hall, Shrewsbury.*
1879 Nov. 14		Rev. James Law	Challis, M.A., *The Vicarage, Stone, Aylesbury.*
1864 Feb. 12		George Fredk.	Chambers, *Northfield, Eastbourne, Sussex.*
1895 Jan. 9		Major W. St. L.	Chase, V.C. F.R.G.S., 28th Bombay Pioneers, *Kirkee, Bombay, India.*
1899 Apr. 14		Samuel	Chatwood, M.Inst.M.E. F.R.G.S., *Broadoak Park, Worsley, Manchester.*
1871 Mar. 13	*	W. H. MAHONEY	CHRISTIE, C.B. M.A. F.R.S., Astronomer Royal, VICE-PRESIDENT, PAST PRESIDENT, *Royal Observatory, Greenwich, S.E.*
1891 Dec. 11		Lord Edw. Spencer	Churchill, 28 *Grosvenor Street, W.*
1897 Feb. 12		John Charles	Clancey, F.R.G.S. F.S.I., Assistant Director of Land Records and Agriculture, *Rangoon, Burma.*
1891 Mar. 13		Thomas Richard	Clapham, *Austwick Hall, Clapham, Lancaster.*
1894 June 8		Rev. John Thos. W.	Claridge, M.A., 3 *Albert Road, Tamworth, Staffordshire.*
1896 Feb. 14		Thomas Folkes	Claxton, Director of the Royal Alfred Observatory, *Mauritius.*
1897 May 14		Arthur W.	Clayden, M.A. F.G.S., *St. John's, Polsloe Road, Exeter.*
1860 Apr. 13	*	Robert Bellamy	Clifton, M.A. F.R.S., Professor of Experimental Philosophy in the University of Oxford, 3 *Bardwell Road, Banbury Road, Oxford.*
1859 Feb. 11		John Francis	Cole, *Westfield, Cheam Road, Sutton, Surrey.*

Date of Election.			
1868 Jan. 10		Major-Gen. A. W.	Drayson, R.A., 20 *Ashburton Road, Southsea*; and *Royal Alfred Yacht Club, Southsea, Hants.*
1875 Mar. 12		John L. E.	Dreyer, Ph.D., *Observatory, Armagh, Ireland.*
1888 Apr. 13		John Edmund	Drower, *Warwick House, Mount Ephraim Road, Streatham, S.W.*
1894 Nov. 9		Major Archd. S.	Drummond, *Guards' Club, Pall Mall*; and 117 *Ashley Gardens, S.W.*
1889 Nov. 8		Philip Freeling	Duke, *Hendon, Middlesex.*
1882 Dec. 8		Hon. Cecil	Duncombe, *The Grange, Nawton, R.S.O., North Yorkshire.*
1876 Mar. 10		John William	Durrad, 39 *St. Peter's Road, Leicester.*
1877 Jan. 12		Rev. Daniel	Dutton, F.G.S., *The Manse, Caversham, Dunedin, New Zealand.*
1894 Apr. 13	*	Frank Watson	Dyson, M.A., Secretary, *Royal Observatory, Greenwich, S.E.*; and 6 *Vanbrugh Hill, Blackheath, S.E.*
1880 May 14		Lindsay Atkins	Eddie, *Oatlands, Grahamstown, Cape of Good Hope.*
1894 May 11		Rev. Fras. John	Eld, M.A., *Polstead Rectory, Colchester.*
1896 June 12		Ernest W.	Ellerbeck, *The Observatory, Scarborough.*
1859 July 8		Robt. Lewis John	Ellery, C.M.G., F.R.S., *Melbourne, Victoria.*
1893 June 9		Edwin Bailey	Elliott, M.A., F.R.S., Waynflete Professor of Pure Mathematics and Fellow of Magdalen College, 4 *Bardwell Road, Oxford.*
1898 June 10	*	Henry	Ellis, *Inglefield, Little Heath, Potter's Bar, Middlesex.*
1864 Dec. 9	*	William	Ellis, F.R.S., F.R.Met.Soc., 12 *Vanbrugh Hill, Blackheath, S.E.*
1872 Feb. 9	*	Isaac	Engelson (*No address: see slip.*)
1872 Feb. 9	*	J. Kennedy	Esdaile, M.A., *Hazelwood, Horsted Keynes, Sussex.*
1878 Jan. 11		Rev. T. H. E. C.	Espin, M.A., *Wolsingham Observatory, Tow Law, R.S.O., Co. Durham.*
1898 May 13		Edward Iszatt	Essam, *Billingborough, Lincolnshire.*
1863 Feb. 13	*	William	Esson, M.A., F.R.S., Savilian Professor of Geometry, *Merton College, Oxford.*
1895 Feb. 8		Chas. Roberts D'	Esterre, 39 *Great Ormond Street, W.C.*, and *Westerham Woods, Alumhurst Road, Bournemouth.*
1858 Mar. 12	*	Rev. Charles	Evans, M.A., 41 *Lancaster Gate, Hyde Park, W.*
1882 June 9		Franklen George	Evans, J.P., F.R.Met.Soc., *Llwynarthan, Castleton, near Cardiff, South Wales.*

Date of Election.			
1886 Jan. 8		Joseph Edward	Evans, B.A., 14 *Royal Place, Greenwich, S.E.*
1896 Nov. 13		Lewis	Evans, J.P. F.S.A., *Barnes Lodge, King's Langley, Herts.*
1894 Jan. 12	*	John	Evershed, Jun., *Kenley, Surrey.*
1858 Dec. 10		Rev. Adam Storey	Farrar, D.D., *The College, Durham.*
1889 Jan. 11	*	Samuel	Fellows, *Tynwald Villas, Lower Villier Street, Wolverhampton.*
1895 June 14	*	John A.	Ferguson, 1 and 2 *Ferguson Building, Denver, Colorado, U.S.A.*
1887 June 10		Capt. A. Mostyn	Field, R.N., *Minnick Wood, Holmwood, Surrey.*
1893 Mar. 9	*	Gerard Brown	Finch, M.A., 1 *St. Peter's Terrace, Cambridge.*
1873 Nov. 14	*	Wm. Henry	Finlay, M.A., *Dalrymple House, Rickmansworth, Herts.*
1864 May 13		Henry Philip	Finlayson, *Avenue Villas, Frith Road, Dover.*
1890 Nov. 14	*	Hon. Justice	Robert Isaac Finnemore, J.P. F.R.Hist.S., *Supreme Court, Pietermaritzburg, Natal.*
1883 Dec. 14		Maj. C. Hawkins	Fisher, *The Castle, Stroud, Gloucestershire.*
1892 Dec. 9		Capt. James	Fisher. (*No address: see slip.*)
1887 Jan. 14		Shelley	Fisher, 48 *Primrose Mansions, Prince of Wales Road, Battersea Park, S.W.*
1891 May 8		Alfred Henry	Fison, D.Sc. *University College, Gower Street, W.C.*; and 25 *Blenheim Gardens, Willesden Green, N.W.*
1878 Apr. 12		Camille	Flammarion, *Rue Cassini* 16, *Avenue de l'Observatoire, Paris*; and *Observatoire de Juvisy, Seine-et-Oise, France.*
1878 Jan. 11		Rev. David	Fleming, *Vicarage, Coxhoe, R.S.O., Co. Durham.*
1884 Apr. 9		Capt. Duncan	Forbes, 169 *High Street, Southampton.*
1873 Jan. 10	*	George	Forbes, M.A. F.R.S. M.Inst.C.E. M.Inst.E.E., 34 *Great George Street, Westminster, S.W.*
1898 May 13	*	Hon. Geo. Stuart	Forbes, H.M. India Civil Service, *Ootacamund, Madras Presidency, India.*
1893 Mar. 10		James Arthur	Formoy, F.C.S., *Chestham, Grange Road, Sutton, Surrey.*
1895 May 10	*	Andrew Russell	Forsyth, Sc.D .L.L.D. F.R.S., Sadlerian Professor of Pure Mathematics, *Trinity College, Cambridge.*
1895 Dec. 13		Major Kingsley O.	Foster, J.P., *Shenley, Redhill, Surrey.*
1889 Dec. 13	*	Alfred	Fowler, *Royal College of Science, South Kensington, S.W.*
1896 Jan. 10		Alpin G.	Fowler, M.Inst.C.E., 1 *Cambridge Road, Norbiton, Surrey.*
1851 June 13	*	William	Francis, Ph.D. F.L.S., *care of Taylor & Francis, Red Lion Court, Fleet Street, E.C.*

Date of Election.			
1899 Apr 14		Rev. W. B. K.	Francis, R.N., *H.M.S. 'Boscawen,' Portland, Dorset.*
1897 Apr 9	*	John	Franklin-Adams, *Wimbledon;* and *Machrihanish House, Campbeltown, Scotland.*
1880 Jan. 9	*	William Sadler	Franks, *care of Isaac Roberts, F.R.S., Starfield, Crowborough, Sussex.*
1871 Nov 10		Joseph H.	Freeman, 98 *Romford Road, Stratford, E.*
1896 April 10		Thomas Frederick	Furber, *Trigonometrical Survey of N.S.W., Department of Lands, Sydney, New South Wales, Australia.*
1881 Feb. 11		W. H. St. Quintin	Gage, *High Street, Wolsingham, Darlington.*
1893 May 12		Walter Frederick	Gale, M.R.S. of N.S.W., *The Observatory, Paddington, New South Wales, Australia.*
1893 Feb 10		Rev. Edwin G.	Gange, *Regent's Park Chapel, Park Square East, N.W.*
1870 Jan. 14	*	William	Garnett, *Low Moor, Clitheroe, Lancashire.*
1870 May 13	*	Charles Henry	Gatty, LL.D. F.R.S.E., *Felbridge Place, East Grinstead, Sussex.*
1872 Dec 13	*	Edward	Gay, *Invermore, Oxford.*
1894 Nov 9		S. Maitland Baird	Gemmill, *care of W. L. Wilson,* 254 *St. George's Road, Glasgow.*
1894 Mar. 9		Augustin Stanis.	Ghosh, 1 *Northumberland Place, Bayswater,* W.
1892 Mar. 11		Arthur	Gibbons, *Science, Art, and Technical School,* and *Albion House, Brierley Hill, Dudley, Staffordshire.*
1857 Jan 9		William Bolger	Gibbs, *Thornton, Beulah Hill, Upper Norwood, S.E.*
1867 Dec. 13	*	David	Gill, C.B. LL.D. F.R.S., Her Majesty's Astronomer, *Royal Observatory, Cape of Good Hope*
1888 Jan. 13		James	Gill, *Nautical College, Colquitt Street, Liverpool*
1841 May 14	*	James	Glaisher, F.R.S., *The Shola, Heathfield Road, South Croydon.*
1871 Apr. 14	*	J. W. L.	GLAISHER, M.A. Sc.D. F.R.S., VICE-PRESIDENT, PAST PRESIDENT, *Trinity College, Cambridge.*
1874 May 8	*	Joseph	Gledhill, *Bermerside Observatory, Skircoat, Halifax.*
1893 Apr. 14	*	Raymond Hill	Godfrey, F.R.G.S., 79 *Cornhill, E.C.*
1885 Jan. 9		Walter	Goodacre, 1 *Birchington Road, Crouch End, N.*
1889 Jan. 11	*	John Jas. Lewis	Goodridge, 38 *St. Deny's Road, Portswood, near Southampton.*
1891 May 8		Thomas	Gordon, F.R.Met. Soc., 9 *Scotch Street, Whitehaven, Cumberland.*
1878 Mar 8		John Ellard	Gore, M.R.I.A., 3 *St. Mary's Road, Dublin, Ireland.*

Date of Election.			
1883 Nov. 9		Eugen von	Gothard, *The Observatory, Herény, bei Stein-amanger, Hungary.*
1896 April 10		Frank L.	Grant, M.A., 58 *Kelvingrove Street, Glasgow, Scotland.*
1881 May 13		Thomas Percy	Gray, 36 *Kylemore Road, West Hampstead, N.W.*
1895 Jan. 11		Charles Josephus	Green, M.R.C.S. L.S.A., 10 *St. Paul's Square, Preston, Lancashire.*
1875 Feb. 12		Nathaniel E.	Green, *care of the Rev. L. G. Bomford, Colney Heath Rectory, St. Albans.*
1896 Nov. 13	*	John Anderton	Greenwood, B.A. LL.M., *Funtington House, near Chichester, Sussex.*
1890 Feb. 14		Richard A.	Gregory, 19 *Westover Road, Wandsworth Common, S.W.*
1898 Jan. 14		Edward John	Griffin, Commr. R.N.R., *R.M.S. 'Moor,' Union Steamship Company, Shanghai, China.*
1878 Feb. 8		John E.	Griffith, *Bryn Dinas, Upper Bangor, North Wales.*
1866 Nov. 9	*	Lord	Grimthorpe, M.A. LL.D. Q.C., 33 *Queen Anne Street, W.*
1870 Nov. 11		Sir Howard	Grubb, F.R.S. M.I.C.E.I., Honorary Master of Engineering, University of Dublin, 51 *Kenilworth Square, Rathgar, Dublin.*
1891 Jan. 9	*	Rev. H. Grattan	Guinness, D.D. F.R.G.S, *Harley House, Bow, E.*; and *Cliff House, Curbar, viâ Sheffield.*
1873 Nov. 14		Col. Gardiner F.	Guyon, Commanding 7th Regimental District, *Egerton House, Richmond, Surrey.*
1879 May 9	*	George Thorn	Gwilliam, 145 *Salcott Road, Wandsworth Common, S.W.*
1896 Jan. 10		David Edward	Hadden, *Alta, Buena Vista Co., Iowa, U.S.A.*
1891 May 8	*	George E.	Hale, D.Sc., Director of the Yerkes Observatory, *Williams Bay, Wisconsin, U.S.A.*
1878 Mar. 8	*	Rev. Frederic J.	Hall, M.A., *Northaw Place, Potter's Bar, Hertford.*
1899 Feb. 10		John James	Hall, *Observatory Cottage, Datchet Road, Slough, Bucks.*
1878 May 10		Maxwell	Hall, M.A., *Montego Bay, Jamaica*; and *care of Miss Hall*, 10 *Osborne Road, Clifton, Bristol.*
1891 Feb. 13		G. P. Blackwood	Hallowes, 48 *Queen Anne's Road, York.*
1895 Jan. 11		Frederic	Hammond, F.R.I.B.A., 38 *Mercers Road, Upper Holloway, N.*
1892 Nov. 11		Herbert	Hancock, M.A. F.R.Met.Soc., *Hipperholme Grammar School, Halifax, Yorks.*
1899 Jan. 13		Arthur	Hands, M.R.C.S., L.R.C.P., *Inkerman House, Wednesfield Road, Wolverhampton.*

.. 79 Nov. 14		William Charles	H
1878 Feb. 8		Henry Burdett	H
1885 Jan. 9		Rev. Andrew	H
1890 May 9	*	Lt.-Col. George	H
1890 Feb. 14		Fredk. William	He
1864 Feb. 12		John B. N.	He
1887 Apr. 6		Capt. M. W. C.	Hej
1897 Mar. 12		J. Harold	Her
1867 Mar. 8	*	Prof. Alex. Stewart	Her
1872 Feb. 9	*	Col. John	Hen
1890 Nov. 14		George	Higg
1893 Dec. 8	*	Captain Edm. H.	Hill
1899 Jan. 13	*	Arthur Robert	Hink
1891 Feb. 13	*	Shin	Hira
1895 Mar. 8		George Denton	Hirs
1895 June 14		Ernest William	Hob
1878 Mar. 8		William	Hob
1895 Mar. 8		Samuel V	H

Date of Election.			
1884 Dec. 12		Henry Park	Hollis, B.A., *Royal Observatory, Greenwich* ; and 2 *Foyle Road, Blackheath, S.E.*
1868 June 12		Henry William	Hollis, *Whitworth House, Spennymoor.*
1885 Apr. 10		Rev. James Hardy	Honeyburne, M.A. (*No address: see slip.*)
1879 Mar. 14	*	Maures	Horner, *Mells, Frome, Somerset.*
1884 Apr. 9		Charles	Horsley, M.Inst.C.E. F.G.S., 174 *Highbury New Park, N.*
1873 Dec. 12	*	Joseph	Hough, M.A., *Codsall Wood, near Wolverhampton.*
1881 Jan. 14		Elijah	Howarth, *Public Museum, Weston Park, Sheffield.*
1861 Mar. 8		Rev. Frederick	Howlett, M.A., 7 *Princes Buildings, Clifton, Bristol.*
1898 Feb. 11	*	Thomas Charlton	Hudson, B.A., '*Nautical Almanac*' *Office*, and 37 *Lambton Road, Hornsey Rise, N.*
1854 Apr. 12	*	Sir WILLIAM	HUGGINS, K.C.B. D.C.L. LL.D. Ph.D. F.R.S., FOREIGN SECRETARY, PAST PRESIDENT, 90 *Upper Tulse Hill, S.W.*
1898 Feb. 11		David	Hunter, *St. Ronan's, Lanark, Scotland.*
1885 Dec. 11		James	Hunter, F.R.C.S.E. F.R.P.S. F.R.S.E., *Rosetta, Liberton, Midlothian, Scotland.*
1886 Dec. 10		Rev. Robt. Sparke	Hutchings, *The Vicarage, Alderbury, Salisbury.*
1887 Jan. 14		Cuthbert	Hutchinson, *Rock Lodge, Roker, near Sunderland.*
1887 June 10		Herbert	Ingall, 1 *Champion Grove, Champion Hill, S.E.*
1879 Jan. 10		Robert T. A.	Innes, *Royal Observatory, Cape of Good Hope.*
1874 Nov. 13	*	Lord	Inverclyde, *Castle Wemyss, Wemyss Bay, Greenock, Scotland.*
1861 Feb. 8	*	Richard	Inwards, 20 *Bartholomew Villas, Kentish Town, N.W.*
1886 Jan. 14		William Edward	Jackson, *Constantinople.*
1888 Jan. 13	*	George James	Jacobs, *Lansdowne, Guildford, Surrey.*
1890 Nov. 14		Harold	Jacoby, B.A. Ph.D., Adjunct Professor of Astronomy, *Astronomical Observatory, Columbia University, New York City, U.S.A.*
1892 May 13	*	Otto	Jaffe, 10 *Donegall Square South, Belfast, Ireland.*
1898 Mar. 11		Rev. Kingsbury	Jameson, M.A., *Highfield, Hendon.*
1891 Jan. 9		Charles W. H.	Jeavons, *Horseley Place, Tipton, Staffordshire.*
1878 Nov. 8		Benjamin George	Jenkins, 43 *Chatsworth Road, West Dulwich, S.E.*
1894 Apr. 13		Griffith Parry	Jenkins, *National Provincial Bank, Colwyn Bay, North Wales.*
1892 May 13		Charles Henry	Johns, M.A., 39 *Cheriton Gardens, Folkestone.*
1888 May 11		Alfred Robert	Johnson, M.A., 13 *Victoria Terrace, Mount Radford, Exeter.*

1895 Dec. 13	* Rhisiard Llewelyn	Jones, Coll... *Mad...*
1892 Apr. 8	Louis J. W.	Joyner (
1867 May 10	* John	Joynson, *Crosb...*
1894 Jan. 12	Joshua	Jukes, *St...*
1890 Mar. 14	James Edward	Keeler, I... *San J...*
1894 Apr. 13	Wm. Redfern	Kelly, M. ... *fast, ...*
1868 Nov. 13	* Lord	Kelvin, M... Natur... Glasg...
1893 May 12	Rev. Philip H.	Kemptho...
1891 Mar. 13	Arthur	Kennedy, *Surre...*
1893 June 9	* Arthur E.	Kennelly, *Street,*
1864 Jan. 8	* David Joseph	Kennelly,
1880 June 11	George	Kilgour, *dress:*
1896 Jan. 10	Rev. Robert	Killip, *St.* *Lanca...*
1859 May 13	Rev. Samuel	Kinns, Ph... *N.W.*
1881 Jan. 14	* Sydney T.	Klein, F.I... *Reigat...*
1896 Jan. 10	George H...	...

Date of Election.			
1878 Jan. 11		Lt.-Col. H.S.G.S.	Knight, *Army and Navy Club, Pall Mall, S.W.*; and *The Observatory, Harestock, Littleton, near Winchester.*
1896 Mar. 13		Thomas Edward	Knightley, *Clive House, Tulse Hill, S.W.*
1873 Mar. 14		EDWARD BALL	KNOBEL, TREASURER, PAST PRESIDENT, 32 *Tavistock Square, W.C.*
1890 Jan. 10		Vernon Edwin	Knocker, *Castle Hill House, Dover.*
1895 Mar. 8	*	Lieut. Henry T. C.	Knox, F.R.G.S., late R.N., 17 *Upper Montagu Street, W.*
1870 Apr. 8	*	Carlton John	Lambert, M.A., *Royal Naval College, Greenwich, S.E.*
1874 May 8		William James	Lancaster, F.C.S. F.G.S. F.R.M.S., *Colmore Row, Birmingham.*
1895 Feb. 8		George Darley	Lardner, *Claraville, Felpham, Sussex.*
1899 Feb. 10	*	Joseph	Larmor, M.A. D.Sc. F.R.S., *St. John's College, Cambridge.*
1873 Jan. 10	*	Edwin	Lawrence, 13 *Carlton House Terrace, S.W.*
1888 Nov. 9	*	Arthur Herbert	Leahy, M.A., *Firth College, Sheffield.*
1876 Feb. 11	*	Rev. Edmund	Ledger, M.A., *Protea, Reigate, Surrey.*
1869 Feb. 12	*	John	Lee, *St. Peter's Chambers, Cornhill, E.C.*
1892 Jan. 8		Edward Herbert	Lees, *Fairhaven, Mallacoota, East Gippsland, Victoria, Australia.*
1894 Jan. 12		Henry Alfred	Lenehan, *Government Observatory, Sydney, New South Wales, Australia.*
1855 Feb. 9		William	Lethbridge, *Courtlands, Lympstone, Devon.*
1894 Jan. 12		Armin Otto	Leuschner, A.B. Assistant Professor of Astronomy in the University of California, *Berkeley, California, U.S.A.*
1871 Mar. 10		Fredk. Wm.	Levander, 30 *North Villas, Camden Square, N.W*
1897 Feb. 12		Rev. Edw. Spry	Leverton, M.A., *School House, Kirkham, Lancashire.*
1884 Dec. 12		Thomas	Lewis, *Royal Observatory, Greenwich, S.E.*
1873 Feb. 14	*	William J.	Lewis, Professor of Mineralogy in the University of Cambridge, *Mineralogical Museum, Cambridge.*
1873 Feb. 14	*	Adolph F.	Lindemann, *Sidholme, Sidmouth, Devon.*
1899 Apr. 14		Capt. Windeyer G.	Lingham, 1 *Caldervale Road, Clapham, S.W.*
1877 Jan. 12	*	Louis Stromeyer	Little, B.A. M.D., *Ashdown, Bletchingley, Surrey*; and *Reform Club, Pall Mall, S.W.*
1897 Dec. 10		Wm. Jas. Stewart	Lockyer, M.A. Ph.D., 16 *Penywern Road, Earl's Court, S.W.*
1874 Nov. 14	*	Sir Edmund Giles	Loder, Bart., M.A., *Leonardslee, Horsham, Sussex.*
1886 Jan. 8	*	Jacob Gerhard	Lohse, *Fünfhausen, bei Elsfleth, Germany.*

1862 Feb. 14	*	William Thynne	Lynn
1880 June 11		Major F. Denis F.	MacC
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1896 Jan. 10		Frederick William	McC.
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1882 Nov. 10		Jonadab	McCa
1877 Mar. 9		Frank	McCle
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1886 May 14		John David	McClu
1873 Jan. 10		William John	Macdo
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1894 Jan. 12		Henry	MacEw
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1892 May 13		William Grant	MacGr
1887 Jan. 14		Capt. Thomas	Macke
1885 Apr. 10	*	James	McKer
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1873 Mar. 14	*	John	M'Lan
			ham
1884 Dec. 12	*	The Hon. Lord	McLar
1897 Jan. 8		Major Percy Alexr.	MacMa
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1879 Mar. 14		Col. Ernest E.	Markw
			Gu
1875 Jan. 8		Charles H.	Marten
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1854 Feb. 10	*	Arthur B.	Mart

Date of Election.			
1898 June 10		Peter	Matthews, *care of Zach. Cartwright, Ltd.*, 102 *Fenchurch Street, E.C.*
1875 Feb. 12		Edward Walter	Maunder, *Royal Observatory, Greenwich, S.E.*; and 18 *Walerand Road, Lewisham Hill, S.E.*
1888 Dec. 14		William Henry	Maw, 18 *Addison Road, Kensington, W.*
1887 Dec. 9	*	Major Somerset H.	Maxwell, *Arley Cottage, Mount Nugent, Co. Cavan, Ireland.*
1895 May 10	*	John Willoughby	Meares, Electrical Engineer to Government of Bengal, *Writer's Buildings, Calcutta, India.*
1889 Feb. 8		Arthur B. P.	Mee, 4 *Park Terrace, Penhill, Cardiff, South Wales.*
1877 Mar. 9	*	Raphael	Meldola, F.R.S. F.C.S., *Finsbury Technical College, Leonard Street, City Road, E.C.*; and 6 *Brunswick Square, W.C.*
1870 Mar. 11		Charles	Meldrum, C.M.G. M.A. LL.D. F.R.S., *care of* W. P. Meldrum, *University Hall, Riddle's Court, Edinburgh.*
1859 Mar. 11	*	John James	Mellor, M.P., *The Woodlands, Whitefield, near Manchester.*
1883 June 8	*	Thomas Kilner	Mellor, *Vernon Avenue, Huddersfield.*
1896 Jan. 10		Charles J.	Merfield, *Railway Construction, Public Works, Sydney, New South Wales, Australia.*
1886 Feb. 12		Duncan	Milligan, 21 *Spencer Road, New Wandsworth, S.W.*
1893 Mar. 10		John	Mills, 11 *Henrietta Street, Covent Garden, W.C.*
1891 Jan. 9	*	John	Mitchell, Jun., *Brockholes, Huddersfield.*
1890 Dec. 12	*	Rev. John Cairns	Mitchell, B.D., *Rutland Cottage, Parkgate Road, Chester.*
1881 Mar. 11		James Henry	Mitchiner, *The Acacias, Barham Road, South Croydon.*
1892 Feb. 12		Arthur Hilton W.	Molesworth, B.A., 15 *Park Lane, W.*
1898 June 10	*	Capt. Percy B.	Molesworth, R.E., *Trincomali, Ceylon.*
1886 Apr. 9		Wm. Hy. Stanley	Monck, M.A., 16 *Earlsfort Terrace, Dublin.*
1893 June 9		Benj. Theophilus	Moore, M.A. M.Inst.C.E., *Longwood, Bexley, Kent.*
1879 Jan. 10		Rev. John H.	Morgan, *Hillside, Woburn Sands, Bucks.*
1886 Feb. 12		Colonel W. G.	Morris, R.E., C.R.E., South Africa, *Cape Town.*
1874 Dec. 11		John Fletcher	Moulton, M.A. Q.C. F.R.S., 57 *Onslow Square, South Kensington, S.W.*
1885 Jan. 9	*	Asutosh	Mukhopadhyay, M.A. LL.D. F.R.S.E., Professor of Mathematics at the Indian Association for the Cultivation of Science, 77 *Russa Road North, Bhowanipur, Calcutta, India.*
1863 Jan. 9	*	Richard	Munday, *Calverley, Plymouth.*

Date of Election.			
1885 Jan. 9		Kavasjee D.	Naegamvala, M.A., *The Maharajah Takhtasingji Observatory, Poona, India.*
1889 Jan. 11	*	Frederick Wm.	Nash, *The Firs, Bentley Heath, Knowle, Warwickshire.*
1875 Dec. 10		Commr. Chas. B.	Neate, R.N., *Sibertswold, Dover.*
1888 May 11		Reginald Carter	Nelson, 19 *Roker Terrace, Sunderland.*
1873 Feb. 14		Edmund Neville	Nevill, Government Astronomer, *Observatory, Durban, Natal.*
1891 June 12	*	HUGH FRANK	NEWALL, M.A., SECRETARY, *Madingley Rise, Cambridge.*
1888 Apr. 13	*	George James	Newbegin, *Thorpe St. Andrew, Norwich.*
1875 Dec. 10	*	Francis Murray	Newton, *Burton Grange, Taunton.*
1877 Apr. 13	*	Frederic	Newton, 3 *Fleet Street, E.C.*
1862 May 9		John	Newton, *Sailors' Home, Dock Street, E.*
1887 May 13	*	Gustavus William	Nicolls, *Caixa 776, Rio de Janeiro, Brazil.*
1854 June 9		Sir Andrew	Noble, K.C.B. F.R.S., *Jesmond Dene House, Newcastle-on-Tyne.*
1890 Jan. 10	*	Benjamin	Noble, F.S.S., *Westmoreland House, Low Fell, Gateshead.*
1855 June 8	*	Capt. William	Noble, *Forest Lodge, Maresfield, Uckfield, Sussex.*
1897 May 14		Herbert L. N.	Noel-Cox, 15 *Ridley Place, Newcastle-on-Tyne.*
1889 Nov. 8		James	Oddie, J.P. F.G.S. F.R.G.S., *Observatory, Ballaarat, Victoria, Australia.*
1881 May 12		Samuel	Okell, *Overley, Langham Road, Bowdon, near Manchester.*
1853 Jan. 14	*	Adm. Sir Erasmus	Ommanney, C.B. LL.D. F.R.S. F.R.G.S., *United Service Club, Pall Mall;* and 29 *Connaught Square, Hyde Park, W.*
1886 Jan. 8	*	William Irving	Page, F.R.G.S., *Wimbledon Common, Surrey.*
1895 June 14	*	Rev. Jas. Dunne	Parker, LL.D. D.C.L. F.R.Met.Soc., *Bennington House, Stevenage, Herts.*
1868 Feb. 14	*	John	Parnell, *Hadham House, Upper Clapton, E.*
1899 June 9		Frederick Evan	Peach, 161 *Stanstead Road, Forest Hill, S.E.*
1887 Jan. 14	*	Horace	Pearce, F.G.S. F.L.S., *The Limes, Stourbridge.*
1877 Jan. 12	*	Robert	Pearce, *Church Court Chambers, Old Jewry, E.C.*
1885 Mar. 13		William	Peck, F.R.S.E., 6 *Hanover Street, Edinburgh* and *City Observatory, Calton Hill, Edinburgh.*
1884 Jan. 11	*	Sir Cuthbert E.	Peek, Bart., M.A. F.S.A., *Rousdon Observatory, Lyme Regis;* and 22 *Belgrave Square, S.W.*
1879 Jan. 10		Charles	Pendlebury, M.A., *St. Paul's School, Kensington, W.;* and 53 *Gunterstone Road, West Kensington, W.*
1867 Feb. 8		Francis Cranmer	Penrose, M.A. D.C.L. Litt.D. F.R.S., *Coleby Field, Wimbledon, S.W.*

Date of Election.			
1885 June 12		Rev. Thomas	Perkins, M.A., *Turnworth Rectory, Blandford, Dorset.*
1895 Feb. 8	*	Chas. Wm. Dyson	Perrins, *Davenham Bank, Malvern.*
1889 May 10		James George	Petrie, *Penrhyn Lodge, Woodberry Down, N.*
1882 Apr. 14		Robert Thomas	Pett, *Royal Observatory, Cape of Good Hope.*
1870 Jan. 14	*	J. E. Hunter	Peyton, 13 *Fourth Avenue, Brighton.*
1899 May 12		Rev. Theodore E. R.	Phillips, M.A., *Handford Vicarage, Yeovil, Somerset.*
1891 Jan. 9		William M.	Pierson, 2214 *Van Ness Avenue, San Francisco, California, U.S.A.*
1861 Dec. 13		The Rt. Hon. Lord	Pirbright, P.C. F.R.S., 42 *Grosvenor Place, S.W.*
1872 June 12	*	Major Chas. Fred.	Plant, *Mon Repos, Wickham Terrace, Brisbane, Queensland, Australia.*
1879 May 9		William Edward	Plummer, M.A., *Liverpool Observatory, Bidston, Birkenhead.*
1893 Nov. 10		Charles Lane	Poor, Ph.D., *Johns Hopkins University;* and 1312 *Eutau Place, Baltimore, Md., U.S.A.*
1885 Jan. 9	*	Rev. T. Cunninghm	Porter, B.A., *Eton College, Windsor.*
1895 Feb. 8		Charles A.	Post, 16 & 18 *Exchange Place, New York City;* and *Strandhome, Bayport, Suffolk County, N.Y., U.S.A.*
1894 Mar. 9		Walter A.	Post, *Newport News, Warwick County, Virginia, U.S.A.*
1854 Jan. 13	*	Eyre Burton	Powell, C.S.I. M.A., 25 *Kirkstall Road, Streatham Hill, Surrey.*
1894 May 11		George Carter	Pulsford, *Queen's House, Royal Hospital School, Greenwich, S.E.*
1896 Jan. 10		Hugh Griffith	Quirk, *Bay Mount, Vico Road, Dalkey, Co. Dublin, Ireland.*
1865 Jan. 13	*	William T.	Radford, M.D., *Sidmount, Sidmouth, Devon.*
1893 June 9	*	Arthur A.	Rambaut, M.A., D.Sc., Radcliffe Observer, *Radcliffe Observatory, Oxford.*
1879 Jan. 10		Capt. James	Rankin, *Local Marine Board, Dock Street, E.*
1883 Nov. 9		Robert	Rawson, Assoc. Inst.N.A., *Warblington Villa, Havant, Hants.*
1866 Jan. 12	*	Lord	Rayleigh, M.A. Sc.D. LL.D. D.C.L. F.R.S., *Terling Place, Witham, Essex.*
1893 Dec. 8		Chas. Herbt. Edm.	Rea, A.I.A. F.S.S., 223 *Norwood Road, Herne Hill, S.E.*
1888 Apr. 13	*	Capt. Geo. Wm.	Read, F.R.G.S., *Penwerris, Cathedral Road, Cardiff, South Wales.*
1881 Jan. 14		Rev. Joseph	Reed, M.A. J.P., *The Rectory, Bellingham, Northumberland.*

Date of Election			
1892 Apr. 8		John Krom	Rees, A.M. E.M., Ph.D., Director of the Observatory, and Professor of Astronomy, *Columbia University, New York City, U.S.A.*
1844 May 10		Sir Josiah	Rees, Chief Justice of Bermuda, *Westbury, Hamilton, Bermuda.*
1896 April 10		Edward Ayearst	Reeves, *Royal Geographical Society, 1 Savile Row, W.*
1896 Feb. 14		Robert Fermor	Rendell, B.A., *The Glen, Blackheath Hill, S.E.*
1899 Feb. 10		John H.	Reynolds, 35 *Trinity Road, Birchfield, Birmingham.*
1892 May 13		Capt. Robert	Reynolds, Lieut. R.N.R., *Union Steamship Co., Southampton.*
1898 June 10		William John	Reynolds, 61 *Fairholt Road, Stamford Hill, N.*
1894 Jan. 12		Rev. David Powell	Richards, B.A., *H.M.S. 'Jupiter,' Channel Squadron.*
1876 Feb. 11	*	Rev. Walter J. B.	Richards, D.D., *St. Charles' College, Ladbroke Grove Road, Notting Hill, W.*
1880 Jan. 9	*	Arthur	Riches, *Corolanty, East Cliff, Bournemouth.*
1870 Apr. 8		Edward Henry	Riches, LL.D., *Agra Lodge, South Cliff, Scarborough.*
1894 May 11		W. Rickmer	Rickmers, 5 *Brunswick Gardens, Kensington, W.*
1883 May 11		Emanuel	Ristori, Assoc.M.Inst.C.E., 2 *Halkin Street, S.W.*; and 9 *Victoria Street, Westminster, S.W.*
1898 Apr. 6		William	Ritchie, *City Observatory, Calton Hill, Edinburgh.*
1890 May 9		Frank	Robbins, *City Gas Testing Station*, 10 *Kinghorn Street, Clothfair, E.C.*
1894 Mar. 9		Alex. William	Roberts, D.Sc. F.R.S.E., *Lovedale, Cape Colony*
1872 Feb. 9		Edward	Roberts, F.S.S., *Park Lodge, Eltham, S.E.*
1882 Jan. 13	*	Isaac	Roberts, D.Sc. F.R.S., *Starfield, Crowborough, Sussex*
1890 Apr. 11		Edward	Robinson, 133 *Castelnau Gardens, Barnes, S.W.*
1884 Dec. 12		Rev. W. Jas. Boden	Roome, 25 *Windsor Road, Ealing, W.*
1895 Jan. 11		Rev. Thomas	Roseby, M.A. LL.D., *The Parsonage, Marrickville, New South Wales, Australia.*
1867 Dec. 13	*	Earl of	Rosse, B.A. LL.D. D.C.L. F.R.S., *Birr Castle, Parsonstown, Ireland*; and *Athenæum Club, Pall Mall, S.W.*
1866 Apr. 13	*	Edward John	Routh, M.A. Sc.D. LL.D. F.R.S., Fellow of the University of London, *Newnham Cottage, Queen's Road, Cambridge*
1899 Feb. 10		Chas. Almeric	Rumsey, B.A., *Dulwich College*; and 27 *Park Road, West Dulwich, S.E.*
1871 Feb. 10		Hy. Chamberlaine	Russell, C.M.G. B.A. F.R.S., Government Astronomer, *Observatory, Sydney, N.S. Wales*

Date of Election.			
1893 Apr. 14		Samuel Marcus	Russell, Professor of Mathematics and Astronomy, Imperial College, Pekin, *care of Shanghai Customs, Shanghai, China.*
1866 Jan. 12	*	Thos. Glazebrook	Rylands, *Highfields, Thelwall, near Warrington, Lancashire.*
1876 Apr. 12	*	Sir David L.	Salomons, Bart., M.A., *Broomhill, Tunbridge Wells*
1892 Feb. 12	*	Ralph Allen	Sampson, M.A., *Observatory House, Durham.*
1894 Nov. 9	*	Samuel Arthur	Saunder, M.A., *Wellington College;* and *Fir Holt, Crowthorne, Berks.*
1876 Jan. 14	*	Harris C. L.	Saunders, 95 *Queen's Gate, S.W.*
1866 May 11	*	James Ebenezer	Saunders, F.G.S. F.L.S. F.S.A., 4 *Coleman Street, E.C.*
1895 Dec. 13		Herbert	Savery, M.A., *The College, Marlborough, Wilts.*
1869 Jan. 8	*	Samuel	Saywell, M.A. F.L.S., *The College, Bromsgrove Worcestershire.*
1889 Jan. 11	*	William	Schooling, *Fairholme, Christchurch Road, Surbiton.*
1877 Dec. 14	*	Arthur	Schuster, Ph.D. F.R.S., Professor of Physics in Owens College (Victoria University), *Victoria Park, Manchester.*
1891 Jan. 9		James Lidderdale	Scott, *care of Scott, Harding, & Co., P.O. Box* 120, *Shanghai, China.*
1870 Apr. 8		George Mitchell	Seabroke, Temple Observer, *Rugby.*
1893 Nov. 10	*	Thos. Jefferson J.	See, Ph.D., Professor of Mathematics in the U.S. Naval Observatory, *Georgetown Heights, Washington, D.C., U.S.A.*
1891 Jan. 9	*	Arthur Laidlaw	Selby, M.A., *University College of South Wales and Monmouthshire, Cardiff, South Wales.*
1897 Jan. 8		Beauchamp Prideaux	Selby, J.P., *Pawston, Cornhill-on-Tweed, Northumberland.*
1894 Jan. 12		Richard Pickering	Sellors, B.A., *Government Observatory, Sydney, New South Wales, Australia.*
1884 Dec. 12		Harold	Seward, B.A., *Patent Office, Southampton Buildings, Chancery Lane, W.C.*
1861 Jan. 11		Philip E.	Sewell, *Gurney's Bank, Norwich.*
1899 Mar. 10		Col. Thos. Davies	Sewell, 29 *Grosvenor Road, S.W.*
1893 Dec. 8	*	William	Shackleton, *Royal College of Science, South Kensington, S.W.*
1892 June 10	*	Martin Charles	Sharp, M.A., *Cintra, Hampstead Lane, Highgate, N.*
1890 June 13		Thomas Steele	Sheldon, M.B.Lond., *Parkside, Macclesfield.*
1878 Apr. 12	*	Rev. Alfred J. P.	Shepherd, B.A., *The Rectory, Sulhampstead, Reading.*

Date of Election.		
1891 Jan. 9	* Rev. Walter	Sidgreaves, S.J., *Stonyhurst College Observatory, Blackburn, Lancashire.*
1857 Mar. 13	* James	Simms, 138 *Fleet Street, E.C.*
1851 Jan. 10	* William	Simms, *Albert Lodge, Hope Road, Shanklin, Isle of Wight.*
1890 Apr. 11	Andrew	Simons, F.G.S. F.R.G.S., 21 *Portland Street, Exeter.*
1894 June 8	David Goudie	Simpson, 199 *Camberwell Grove, Denmark Hill, S.E.*
1892 Jan. 8	John Samuel	Slater, Professor of Civil Engineering, *Civil Engineering Coll., Seebpore, Calcutta, India.*
1897 Apr. 9	John Sisson	Slater, M.A. LL.D., 1 *Garden Court, Temple, E.C.*; and *Seafield, Lytham, Lancashire.*
1878 Jan. 11	* Rev. Philip R.	Sleeman, 65 *Pembroke Road, Clifton, Bristol.*
1889 Dec. 13	* David	Smart, L.R.C.P. M.R.C.S. L.S.A., 108 *Grange Road, Bermondsey, S.E.*
1861 Mar. 8	Rev. Maurice A.	Smelt, M.A., *Heath Lodge, Cheltenham.*
1861 May 10	Basil Woodd	Smith, J.P., *Branch Hill Lodge, Hampstead Heath, N.W.*
1884 May 9	* Charles Michie	Smith, B.Sc. F.R.S.E., Government Astronomer, *Observatory, Kodaikánal, Palani Hills, South India.*
1894 June 8	Rev. E. Harrison	Smith, M.A. R.N., *H.M.S. 'Centurion,' China Station.*
1896 Feb. 14	George Albert	Smith, *St. Ann's Gardens, Brighton.*
1896 April 10	* Geo. Fredk. Herbert	Smith, B.A., *British Museum of Natural History, Cromwell Road, S.W.*
1876 Apr. 12	* John Bagnold	Smith, *Newstead Colliery, near Nottingham.*
1891 Jan. 9	John Peter Geo.	Smith, *Sweyney Cliff, Coalport, R.S.O., Shropshire.*
1880 Jan. 9	* Rev. William	Smith, *Acacia Villa, St. Helen's Road, Hastings.*
1897 Feb. 12	William Arthur	Smith, 78 *Hagley Road, Edgbaston*; and 94 *Charlotte Street, Birmingham.*
1846 Mar. 13	* Charles Piazzi	Smyth, LL.D. F.R.S.E., *Clova, Ripon.*
1892 Nov. 11	Alfred Thos. Odell	Sorrell, 39 *Allison Road, Harringay, N.*
1898 June 10	William Edward	Sparkes, 4 *Roker Terrace, Sunderland.*
1895 Mar. 8	Rev. Danl. Higham	Sparling, B.A., *Christchurch Rectory, Biddulph Moor, near Congleton, Cheshire.*
1897 Apr. 9	Rev. John	Spence, 27 *Walpole Street, Chelsea, S.W.*
1883 Jan. 12	Edmund Johnson	Spitta, L.R.C.P. Lond., *Ivy House, Clapham Common, S.W.*
1857 Feb. 13	* W. W. Spencer	Stanhope, *Cannon Hall, Barnsley, Yorkshire.*
1894 Feb. 9	William Ford	Stanley, F.G.S. F.R.Met.Soc., *Cumberlow, South Norwood, S.E.*
1880 Feb. 13	Captain John	Steele, *The Rectory, Flordon, near Norwich.*

f Election.			
June 11		Capt. R. Wright	Sterry, *Local Marine Board, Dock Street, E.*
Feb. 10	*	Charles	Stevens, 10 *Wemyss Road, Blackheath, S.E.*
Mar. 8		Frederick Haller	Stevens, B.A., *Clifton College, Bristol.*
Dec. 11		Capt. Geo. Richd.	Stevens, *Hong Kong, China.*
Jan. 13	*	Robert Norton	Stevens, *Woodham, near Woking Station, Surrey.*
Mar. 14		John T.	Stevenson, *Nelson Street, Auckland, New Zealand.*
Mar. 9	*	Rev. Walter Edw.	Stewart, M.A., *Elcott House, Hurworth-on-Tees, Darlington.*
May 11		William Stewart	Stewart, *Levern, Barrhead, Scotland.*
June 8	*	Sir John Benjamin	Stone, M.P. J.P. F.L.S. F.G.S. F.R.G.S., *The Grange, Erdington, near Birmingham.*
Feb. 10	*	G. Johnstone	Stoney, M.A. D.Sc. F.R.S., 8 *Upper Hornsey Rise, N.*
Jan. 11		John Matthew	Stothard, M.D., *Laurel Lodge, Monkstown, Co. Dublin.*
Mar. 12		Lt.-Col. George	Strahan, R.E., *Dehra Dûn, India.*
Nov. 11		Edward	Stroud, *Coopers' Company's School, Tredegar Square, Bow;* and *Rostellan,* 36 *Thorold Road, Ilford, Essex.*
Jan. 14	*	Ambrose	Swasey, *Cleveland, Ohio, U.S.A.*
Apr. 9		Lewis	Swift, *Lowe Observatory, Echo Mountain, Los Angelos, California, U.S.A.*
Jan. 10	*	Hy. Wm. Lloyd	Tanner, M.A. F.R.S., Professor of Mathematics in the University College of South Wales and Monmouthshire, 27 *Cwrt-y-Fil Road, Penarth, South Wales.*
Jan. 10		Robt. Lethbridge	Tapscott, Assoc.M.Inst.C.E. F.G.S. F.R.Met. Soc., 62 *Croxteth Road, Liverpool.*
Feb. 8		Kenneth James	Tarrant, *Craven Cottage, Bushey Heath, Herts;* and 63 *Threadneedle Street, E.C.*
Nov. 11	*	John	Tatlock, Jun., M.A., *P.O. Box* 194, *New York City, U.S.A.*
Dec. 14		Albert	Taylor, *Gorphwysfa, Cwrt-y-Fil Road, Penarth, South Wales.*
Mar. 11		Alfred	Taylor, *c/o T. Cooke & Sons, Buckingham Works, York;* and *Polvellan, Holgate Hill, York.*
Dec. 14		Basil R. H.	Taylor, *Carlton Club, Pall Mall, S.W.*
Feb. 14		Charles Albert	Taylor, 8 *Cranbourne Court, Albert Bridge, S.W.*
May 8	*	C. H. Brewitt	Taylor, *care of I.M. Customs, Shanghai, China.*
Jan. 13		Harold Dennis	Taylor, *Trenfield, Holgate, York.*
Feb. 12		Rev. Chas. J.	Taylor, M.A. F.C.S., *The Larches, Banstead, Surrey.*
May 14	*	Henry Martyn	Taylor, M.A., *Trinity College, Cambridge.*

Date of Election.			
1886 Dec. 10		Washington	Teasdale, F.R.M.S., *Headingley, Leeds.*
1873 Jan 10		John	Tebbutt, *Observatory, Windsor, New South Wales.*
1896 Apr 10		Theodore Martin	Teed, C.E F.R.G.S., 188 *Camberwell Grove, Denmark Hill, S.E.*
1855 June 8	*	Lt.-Gen. Jas. F.	Tennant, C.I.E. R.E. F.R.S., PAST PRESIDENT, 11 *Clifton Gardens, Maida Hill, W.*
1874 Nov. 13	*	Dr. François	Terby, 96 *Rue des Bogards, Louvain, Belgium.*
1881 Mar. 11	*	Rev. Thomas R.	Terry, M.A., *The Rectory, East Ilsley, near Newbury, Berks.*
1890 Jan 10		Wm. Grasett	Thackeray, *Royal Observatory, Greenwich;* and 32 *Kidbrooke Park Road, Blackheath, S.E.*
1888 May 11		Sir Henry	Thompson, Bart., F.R.C.S. M.B.Lond., 35 *Wimpole Street, W.*
1880 June 11	*	Capt. Peter	Thompson, *Bolton House, Peak Hill, Sydenham.*
1875 May 14		Silvanus Phillips	Thompson, B.A. D.Sc. F.R.S., *Finsbury Technical College, Leonard Street, City Road, E.C.;* and *Morland, Chislett Road, West Hampstead, N.W.*
1885 Jan. 9	*	Capt. Benjamin	Thomson, Lieut. R.N.R., *The Sycamores, High Bickington, Chulmleigh, N. Devon.*
1875 Feb. 12		Wm. Henry	Thornthwaite, *Avonhirst, Camden Park, Chislehurst.*
1892 Jan 8		Arthur	Thornton, M.A., *The Grammar School, Bradford.*
1886 Feb. 12	*	Christopher	Thwaites, M.Inst.C.E., *Burnell Road, Sutton, Surrey.*
1899 Feb 10		William Harold	Tingey, B.A. F.R.Met.Soc., *Rede Court, Rochester, Kent.*
1864 Apr. 8		Sir Charles	Todd, K.C.M.G. M.A. F.R.S., Government Astronomer, *Observatory, Adelaide, South Australia.*
1854 Feb. 10	*	Captain Henry	Toynbee, 12 *Upper Westbourne Terrace, W.*
1886 Jan. 8	*	Julien	Tripplin, 31 *Holborn Viaduct, E.C.;* and 23 *Heathfield Gardens, Chiswick, W.*
1896 Dec. 11		John Burt	Trivett, *Trigonometrical Survey of N.S.W., Department of Lands, Sydney, N.S.W., Australia.*
1895 Nov. 8		Oswald Thomas	Tuck, *H.M.S. 'Repulse,' Channel Squadron.*
1863 May 8	*	Lieut.-Col. G. L.	Tupman, R.M.A., *Hillfoot Observatory, College Road, Harrow.*
1885 Jan. 9	*	Herbert Hall	Turner, M.A. B.Sc. F.R.S., Savilian Professor of Astronomy, Oxford, *University Observatory, Oxford.*
1864 Nov. 11		Edward	Tyer, *Ashwin Street, Dalston, E.*
1883 June 8		Wm. John Vernon	Vandenbergh, F.R.Met.Soc., *care of W. J. Vandenbergh, 39 Allen Road, South Hornsey, N.*
1867 Apr 12	*	Frederick Henry	Varley, 82 *Newington Green Road, Highbury, N.*

Date of Election.			
1898 Jan. 14		John	Vaughan, Lieut. R.N.R., Commr., *China Navigation Company, Shanghai, China.*
1856 Jan. 11		Rev. George	Venables, *Burgh Castle Rectory, near Great Yarmouth.*
1881 Feb. 11		James George	Vine, 14 *Glen Eagle Road, Streatham, S.W.*
1879 Nov. 14		Henry T.	Vivian, *Eversley, Hants.*
1895 Jan. 11		Rev. Peter Hately	Waddell, *The Manse, Whitekirk, Prestonkirk, East Lothian, Scotland.*
1891 Jan. 9	*	Arthur John	Walker, *New College, Oxford;* and *Bayard's Lodge, Knaresborough, Yorkshire.*
1883 Jan. 12	*	William Henry	Walmsley, B.Sc., *'Nautical Almanac' Office,* 3 *Verulam Buildings, Gray's Inn, W.C.*
1893 Nov. 10		Louis Heathcote	Walter, 53 *Victoria Street, S.W.*
1888 May 11		John	Walther, M.D. C.M. F.R.Met. Soc., 109 *Marina, St. Leonards-on-Sea.*
1863 Feb. 13		Col. M. Foster	Ward, *Bannerdown House, Batheaston, Somerset;* and *Partenkirchen, Bavaria.*
1888 Jan. 13	*	Francis James	Wardale, 1 *Whitehall Place, S.W.*
1892 Dec. 9		Francis R.	Wardle, F.R.M.S., 156 *Fifth Avenue, New York City, U.S.A.*
1876 Jan. 14	*	Major-Gen. W. H.	Wardell, R.A., *Beechwood, Winchester.*
1899 Jan. 13	*	Worcester R.	Warner, *Cleveland, Ohio, U.S.A.*
1887 June 10	*	Hy. Addenbrook	Wassell, *Addenbrook Villa, Love Lane, Stourbridge.*
1876 Dec. 8	*	Col. James	Waterhouse, Bengal Staff Corps, *Oak Lodge, Eltham, Kent.*
1884 Feb. 8	*	Frederick William	Watkin, B.A., *St. Paul's School;* and *Colet House, Talgarth Road, West Kensington, W.*
1870 Mar. 11	*	Rev. Hy. Charles	Watson, M.A., *Clifton College, Bristol.*
1885 Apr. 10	*	Lt.-Col. Harry J.	Watson, *The Ridges, Farnborough, Hants.*
1897 Jan 8		John	Watson, *Hollymount, Wilpshire, Blackburn, Lancashire.*
1892 Jan. 8		Wm. Livingstone	Watson, *Ayton, Abernethy, Perthshire;* and 105 *Pall Mall, S.W.*
1878 Jan. 11		Rev. G. E.	Watts, *Kensworth Vicarage, Dunstable, Herts.*
1888 Feb. 10		Rev. W. R.	Waugh, *The Observatory, Portland, Dorset.*
1879 Nov. 14	*	Robert Rumsey	Webb, M.A., *St. John's College, Cambridge.*
1875 June 11		Francis Richard	Wegg-Prosser, M.A., *Merry Hill, Belmont, Hereford.*
1899 Feb. 10		Thomas	Weir, 56 *Parkfield Street, Moss Lane East, Manchester.*
1897 Feb. 12		Edward	Weldon, *Didmarton, Frant Rd., Tunbridge Wells.*
1877 Jan. 12	*	Rear-Adm. Sir W. J. L.	Wharton, K.C.B. F.R.S., Hydrographer for the Admiralty, *Admiralty, Whitehall, S.W.;* and *Florys, Prince's Road, Wimbledon Park.*

Date of Election.			
1869 Jan. 8	*	Edward John	White, *Observatory, Melbourne, Victoria.*
1893 Mar. 10	*	Edward Turner	Whitelow, 70 *Deansgate, Manchester.*
1898 Dec. 9		Charles Thomas	Whitmell, M.A. B.Sc., *Invermay, Headingley, Leeds.*
1898 Feb. 11	*	Edmund Taylor	Whittaker, M.A., *Trinity College, Cambridge.*
1898 Feb. 11		Walter	Wickham, *Radcliffe Observatory;* and 62 *St. John's Road, Oxford.*
1895 Jan. 11		Robert	Wigglesworth, *York;* and 8 *Victoria Street, Westminster, S.W.*
1885 Dec. 11		Richard	Wilding, *Swillbrook House, Bartle, near Preston.*
1899 Feb. 10		Algernon Chas. Legge	Wilkinson, B.A., *Trinity College, Cambridge.*
1895 May 10		William	Willett, Junr., *The Cedars, Chislehurst Common, Kent;* and 2 *Sloane Gardens, S.W.*
1884 May 9	*	Arthur Stanley	Williams, *Bella Vista,* 20 *Hove Park Villas, West Brighton.*
1865 Dec. 8	*	Harry Samuel	Williams, M.A., 6 *Heathfield, Swansea, South Wales.*
1875 Dec. 10	*	William E.	Wilson, F.R.S., *Daramona, Streete, Rathowen, Ireland.*
1860 Mar. 9		Rev. Thomas	Wiltshire, M.A., D.Sc., F.G.S., F.L.S., Emeritus Professor of Geology and Mineralogy, King's College, London; 25 *Granville Park, Lewisham, S.E.*
1898 May 13		Rev. Wm. Edward	Winks, 58 *Richmond Road, Cardiff, South Wales.*
1894 Jan. 12		Max	Wolf, Ph.D., Professor der Astronomie an der Universität, *Astrophysikalisches Observatorium, Heidelberg, Germany.*
1883 May 11		Walter George	Woollcombe, M.A., B.Sc. Lond., *Exeter;* and *King Edward's High School, Birmingham.*
1877 Feb. 9	*	Arthur Mason	Worthington, M.A., F.R.S., *R.N.E. College, Devonport;* and *Mohuns, Tavistock, Devon.*
1879 Jan. 10		Arthur W.	Wright, Ph.D., Professor of Physics at Yale University, *New Haven, Connecticut, U.S.A.*
1867 Apr. 12	*	Stephen M.	Yeates, 2 *Grafton Street, Dublin.*
1862 Dec. 12		Sir Allen	Young, C.B., 18 *Grafton Street, Bond Street, W.*
1890 May 8		Alfred Ernest	Young, Assoc.M.Inst.C.E., *Trigonometrical Survey of Perak, Taiping, Perak, Straits Settlements.*
1893 May 12		James Henry	Young, B.Sc., *Office of Works, Storey's Gate, Westminster, S.W.*
1877 Jan. 12	*	Jesse	Young, F.R.G.S., *Wisbech, Cambridgeshire.*
1898 Jan. 14		Thomas Emley	Young, B.A., Pres. Inst. Actuaries, 108 *Evering Road, Stoke Newington, N.*
1875 June 11		Prof. C. Venceslas	Zenger, *Palais Lobkowitz* 7/III, *Prague, Bohemia.*

ASSOCIATES.

Date of Election.		
1866 May 11	G. F. J. Arthur	Auwers, Ph.D., Professor, *Lindenstrasse* 91, *Berlin, S. W.*
1898 Dec. 9	O.	Backlund, Directeur de l'Observatoire Central Nicolas, *Pulkowa, Russia.*
1882 Nov. 10	H. G. van de Sande	Bakhuyzen, Professor in the University and Director of the Observatory, *Leiden, Holland.*
1898 Dec. 9	Edward Emerson	Barnard, D.Sc. F.R.A.S., *Yerkes Observatory, Williams Bay, Wisconsin, U.S.A.*
1890 Dec. 12	Lewis	Boss, Professor, Director of the Dudley Observatory, *Albany, New York, U.S.A.*
1884 Nov. 14	Theodor	Brédikhine, Emeritus Professor, Doctor of Astronomy, *Imperial Academy of Sciences, St. Petersburg, Russia.*
1898 Dec. 9	Sherburne Wesley	Burnham, M.A. F.R.A.S., *Government Building, Chicago, U.S.A.*
1889 Nov. 8	Seth C.	Chandler, 16 *Craigie Street, Cambridge, Mass., U.S.A.*
1890 Dec. 12	Marie Alfred	Cornu, Membre de l'Académie des Sciences et du Bureau des Longitudes, Professeur à l'École Polytechnique, 9 *Rue de Grenelle, Paris.*
1898 Dec. 9	Colonel Gilbert	Defforges, Correspondant du Bureau des Longitudes, *Bureau français restant de Galata, Constantinople.*
1889 Nov. 8	Nils Christian	Dunér, Ph.D., Professor, Director of the Observatory, *Upsala, Sweden.*
1892 Nov. 11	W. L.	Elkin, Ph.D., *Yale University Observatory, New Haven, Conn., U.S.A.*
1848 May 12	Hervé Aug. Ét. Albans	Faye, Membre de l'Institut et Président du Bureau des Longitudes, 95 *Avenue des Champs-Elysées, Paris.*

Date of Election.		
1866 May 11	Wilhelm	Förster, Professor, Director der Sternwarte, *Enckeplatz 3a, Berlin, S.W.*
1848 May 12	Johann Gottfried	Galle, Ph.D., Professor, *Kiez-Strasse 17, Potsdam, Germany.*
1879 Jan. 10	Asaph	Hall, Professor of Mathematics, U.S. Navy, *2715 N. Street, Washington, D.C., U.S.A.*
1889 Nov. 8	Paul P.	Henry, Astronome à l'Observatoire, *Paris.*
1889 Nov. 8	Prosper M.	Henry, Astronome à l'Observatoire, *Paris.*
1878 Nov. 8	George William	Hill, Ph.D., *West Nyack, N.Y., U.S.A.*
1884 Nov. 14	Edward Singleton	Holden, M.A. Sc.D. LL.D., *care of Smithsonian Institution, Washington, D.C., U.S.A.*
1872 Nov. 8	Jules	Janssen, Membre de l'Institut et du Bureau des Longitudes, Directeur de l'Observatoire d'Astronomie Physique, *Meudon, Seine-et-Oise, France.*
1892 Nov. 11	Jacobus Cornelius	Kapteyn, Ph.D. Professor of Astronomy at the University, *Groningen, Holland*
1898 Dec. 9	James Edward	Keeler, D.Sc. F.R.A.S., Director of the Lick Observatory, *San José, California, U.S.A.*
1883 Nov. 9	Samuel Pierpont	Langley, LL.D., Secretary of the Smithsonian Institution, *Washington, D.C., U.S.A.*
1886 Nov. 12	Maurice	Loewy, Membre de l'Institut et du Bureau des Longitudes, Directeur de l'Observatoire de Paris, 119 *bis, Rue Notre Dame des Champs, Paris.*
1854 June 9	Karl Theodor Robert	Luther, Ph.D., Professor, Astronom der Sternwarte, *Martinstrasse* 101, *Dusseldorf, Germany.*
1894 Nov. 9	Albert A.	Michelson, Ph.D., Professor of Physics in the University, *Chicago, U.S.A.*
1872 Nov. 8	Simon	Newcomb, Professor, 1620 *P Street, Washington, D.C., U.S.A.*
1884 Nov. 14	Magnus	Nyrén, Ph.D., Astronom der Sternwarte *Pulkowa, Russia.*
1883 Nov. 9	J. A. C.	Oudemans, Ph.D., Professor, *Utrecht, Holland.*

of Election.		
June 10	Edward Charles	Pickering, Professor, Director of the Observatory, *Harvard College, Cambridge, Mass., U.S.A.*
Nov. 9	Henri	Poincaré, Membre de l'Institut, Professeur à la Faculté des Sciences, 63 *Rue Claude Bernard, Paris.*
Dec. 9	Henry A.	Rowland, Ph.D. LL.D. F.R.S., Professor of Physics and Director of the Physical Laboratory, *Johns Hopkins University;* and 915 *Cathedral Street, Baltimore, Md., U.S.A.*
May 11	Truman Henry	Safford, B.A. Ph.D., Field Memorial Professor of Astronomy, *Williams College, Williamstown, Mass., U.S.A.*
Nov. 8	Giovanni Virginio	Schiaparelli, Direttore del R. Osservatorio di Brera, *Milan.*
Dec. 9	Wilhelm	Schur, Ph.D., Professor der Astronomie, und Director der Königlichen Sternwarte, *Göttingen, Germany*
Nov. 11	Hugo	Seeliger, Ph.D., Professor der Astronomie an der Universität, Director der Königlichen Sternwarte, *München, Bavaria.*
Nov. 11	Hermann	Struve, Ph.D., Director der Universitäts-Sternwarte, *Königsberg, Germany.*
May 12	Otto	Struve, *Fahnstrasse* 8, *Karlsruhe, Baden, Germany.*
Nov. 9	Pietro	Tacchini, Professore, Direttore dell' Ufficio centrale di Meteorologia e Geodynamica, dell' Osservatorio del Collegio Romano ed annesso Museo, *Via del Cararita* 7, *Rome.*
Nov. 10	Hermann Carl	Vogel, Ph.D., Professor, Director des Königlichen Astrophysikalischen Observatoriums, *Potsdam, Germany.*
Nov. 9	Edmund	Weiss, Ph.D., Professor, Director der K.K. Sternwarte, *Wien (Währing), Austria.*
Jan. 9	Chas. Joseph Étienne	Wolf, Membre de l'Institut, Astronome de l'Observatoire, Professeur à la Sorbonne, 1 *Rue des Feuillantines, Paris.*
Nov. 8	Charles A.	Young, *College of New Jersey, Princeton, New Jersey, U.S.A.*

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